12 APRIL 1979 (FOUO 20/79) 1 OF 1

APPROVED FOR RELEASE: 2007/02/09: CIA-RDP82-00850R000100040031-2

FOR OFFICIAL USE ONLY

JPRS L/8395

12 April 1979

USSR

# TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY
# PHYSICAL SCIENCES AND TECHNOLOGY
# (FOUO 20/79)

## U. S. JOINT PUBLICATIONS RESEARCH SERVICE

FOR OFFICIAL USE ONLY

NOTE

JPRS publications contain information primarily from foreign newspapers, periodicals and books, but also from news agency transmissions and broadcasts. Materials from foreign-language sources are translated; those from English-language sources are transcribed or reprinted, with the original phrasing and other characteristics retained.

Headlines, editorial reports, and material enclosed in brackets [] are supplied by JPRS. Processing indicators such as [Text] or [Excerpt] in the first line of each item, or following the last line of a brief, indicate how the original information was processed. Where no processing indicator is given, the information was summarized or extracted.

Unfamiliar names rendered phonetically or transliterated are enclosed in parentheses. Words or names preceded by a question mark and enclosed in parentheses were not clear in the original but have been supplied as appropriate in context. Other unattributed parenthetical notes within the body of an item originate with the source. Times within items are as given by source.

The contents of this publication in no way represent the policies, views or attitudes of the U.S. Government.

JPRS L/8395

12 April 1979

# TRANSLATIONS ON USSR SCIENCE AND TECHNOLOGY
# PHYSICAL SCIENCES AND TECHNOLOGY

(FOUO 20/79)

## CONTENTS PAGE

CONTENTS (Continued) Page

ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.382.8.381

# CIRCUIT-DESIGN TECHNIQUES FOR REDUCING THE SWITCHING FACTOR IN DIGITAL SYSTEMS BASED ON INTEGRATED INJECTION LOGIC

Kiev IZVESTIYA VUZOV: RADIOELEKTRONIKA in Russian Vol 21, No 12, 1978 pp 37-40

[Article by I. I. Shagurin]

[Text] An examination is made of possible methods of structural organization of digital systems based on $I^2L$ for reducing power consumption P and switching factor A. It is shown that staged connection of injection coupled LSI chips with series-connected injectors reduces the values of A and P by a factor of four, while the use of active-passive supply cuts these parameters by an order of magnitude or more. New types of microcircuits are suggested for realizing these advantages.

Among the bipolar transistor logic circuits, those based on integrated injection logic ($I^2L$) give the lowest switching factors $A = Pt_3$, where P, $t_3$ are the average power consumption and switching delay. Estimates made with consideration of future improvements in techniques for making $I^2L$ microcircuits give a minimum limiting value $A_{min} = (10^{-16}-10^{-17})$ J [Ref. 1]. The best values of A that have been achieved up to the present for individual $I^2L$ circuits are $(2-5)\cdot 10^{-14}$ J [Ref. 1, 2].

However, the practical values of the switching factor realized in injection digital microcircuits under actual working conditions are considerably higher (by a factor of 5-10) since the limiting estimates and experimental data cited above were obtained at rather low supply voltages ($E = 0.15$ V in Ref. 1, $E = 0.8$ V in the experimental tests of Ref. 2). As shown in Ref. 3, to ensure adequately stable operation of injection microcircuits it is necessary to use a supply voltage $E \leq K_{st}U_i$, where $U_i$ is the voltage drop on the open injector junction, $K_{st} = (4-5)$ is the coefficient of power losses to stabilization. In practice, there are also a number of other reasons why it is undesirable to use power supplies with low voltage $E \leq 2$ V in digital devices. Low-voltage supplies have reduced stability, efficiency and load handling capacity. Signal transmission through external circuits with adequate interference immunity requires elevated values of the logical differential, which are attained by a corresponding increase in the supply voltage. Injection microcircuits are ordinarily used together with TTL microcircuits that have a typical supply voltage of 5.0 V. The addition of a low-voltage supply is detrimental to the overall characteristics of the digital device. Under these conditions, the following circuit-design techniques are offered for reducing the switching factor of injection microcircuits.

*Sequential (staged) supply of LSI injectors.* When this method is used, the injector supply circuits of several chips are connected to the power source in sequence (Fig. 1). Two versions are possible for organizing the supply of injection microcircuits in the digital device.

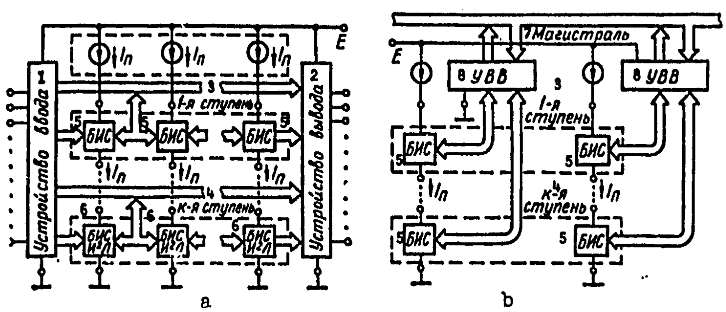



Fig. 1

KEY:
1--Input device
2--Output device
3--First stage
4--k-th stage
5--LSI chip
6--$I^2L$ LSI chip
7--Mainline
8--I/O device

In the case of *direct cascading* (Fig. 1a) the digital system is actually several independent data processing devices (channels) [Ref. 4]. The logic levels of the microcircuits included in the different stages (channels) differ by an amount $\Delta U^0$, $\Delta U^1 = \alpha U_i$, where $\alpha = 1, \ldots, (k-1)$, k is the number of stages (channels). Information can be transferred directly from the lower to the upper channels, and information can be transferred from the upper channels to the lower ones through matching transistors [Ref. 5]. However, in this case there is a considerable reduction in the speed due to the increased logic differential for signals between channels by an amount $\alpha U_i$, and there is an increase in the area of the crystal and the power consumption due to energizing of the matching elements. Therefore it is advisable to keep the number of connections between channels to a minimum.

The input device distributes the information coming in to be processed among the channels of the system, ensuring the required levels of the input logic signals for each channel (stage). In principle, the input device is capable of "paralleling" the solution of a general problem among k channels. In this case the input device includes a programmable permanent memory or microprocessor. The input device transforms signals entering from different channels, providing standard levels of logic signals and the necessary load handling capacity at the output of the system. The output device can also carry out certain logical transformations of information: multiplexing, masking, channel switching and the like.

In the *mainline arrangement* (Fig. 1b) all devices of the digital system exchange information through a common mainline by intermediate I/O devices. The signals in the mainline have unified standard logic levels. The I/O devices ensure forward and reverse conversion of the levels of the logic signals in the mainline and in the injection LSI chips of the different stages. The logic levels of the signals of the different stages differ by $\Delta U^0$, $\Delta U^1$, and therefore the information is exchanged between stages mainly through the I/O devices and the mainline. Direct connection (cascading) is possible only between different LSI chips of a single stage, and also from the outputs of the LSI chips of the lower stages to the inputs of those in the upper stages. The I/O devices in this arrangement, in addition to the functions of transforming logic levels and ensuring the load handling capacity necessary for the mainline, can also perform certain logic functions: multiplexing, various commutation of signals on mainlines and the like.

Supply to the injection LSI chips included in the different stages of the digital system can be most effectively handled by sources of stable current based on p-n transistors, as shown in Fig. 2. These circuits ensure stable operation at voltages $U \geq U_{n.min} \approx 5$ V. By changing resistance R (for instance by commutation of the external leads) we can regulate the supply current $I_n$ of the injection LSI chips, providing the required speed [Ref. 1, 7]. By adding resistor $R_n$ we can make the necessary change in supply current, and hence in the speed of the separate stages of the injection LSI chips. The permissible number of LSI stages in this case is $k = (E_{min} - U_{n.min})/U_{i.max}$. For typical values: $E_{min} = 4.5$ V, $U_{n.min} = 0.5$ V, $U_{i.max} = 1.0$ V, we get $k = 4$.

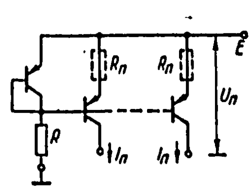
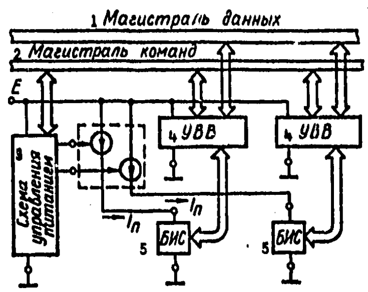



Fig. 2

Thus in the case of series connection of injectors when transistor current sources are used the loss factor $K_{st}$ decreases by a factor of k, reaching $K_{st} \approx 1.2$. As a result, switching factors close to the limiting values [Ref. 1, 2] can be actually realized in digital systems.

*Active-passive supply mode.* When this method is used, the supply currents of the injection LSI chips vary during operation of the digital system from zero to some limiting value $I_n$. Thus a power savings is realized by disconnecting devices from the supply that are not involved in data processing at the given instant, and speed is increased by feeding the maximum current $I_n$ to devices that are involved in data processing [Ref. 6].

The structure of a digital system with active-passive supply mode is shown in Fig. 3. Construction of the system requires controllable current sources.




KEY: 1--Data mainline
2--Command mainline
3--Supply control circuit
4--I/O device
5--LSI chip

Fig. 3

The sources must have high speed for switching current $I_n$ to avoid reducing the speed of the system. Control of the current sources is accomplished by a special microcircuit that analyzes incoming commands and feeds energizing signals to the current supply sources of the devices that are taking part in execution of these commands. Several levels of current supply are possible for executing commands of different priorities.

In order to prevent the operation of supply activation from delaying the solution of a problem, the control device can analyze two successive commands simultaneously so as to pre-energize the supply for the devices required in executing the next command.

The controlling microcircuit may be an appropriately programmed permanent memory, or a special supply-control microprocessor that will handle real-time redistribution of the supply current to the devices in the digital system in accordance with the problem being solved.

Since only some of the circuits (usually no more than 10%) are simultaneously involved in data processing in digital systems, the use of the active-passive supply mode in principle can give a switching factor for logic circuits that is less than the limiting value given in Ref. 1, 2 by a factor of 1/p, where p is the average percentage of circuits involved in processing at each instant.

CONCLUSION

A further reduction in the switching factor of digital microcircuits based on $I^2L$ requires not only continued improvement of manufacturing techniques, but also the solution of circuit design problems for optimum power supply organization. This means that research is needed in the following areas:

*high-quality stable current supplies,* including sources with short on-off time;

*high-speed I/O microcircuits* that can be used in staged energizing of injection LSI chips;

*microcircuits for supply control devices.*

Development of the appropriate current supplies and I/O microcircuits will permit a reduction even on the present stage by a factor of four in the power consumption and accordingly in the switching factor of digital systems based on injection microcircuits.

Realization of the active-passive supply mode will enable a reduction in the average switching factor for many types of digital systems by another order of magnitude or more. To accomplish this, it is necessary first to solve problems of structural organization of digital systems with active-passive supply mode, to define the class of problems where the use of such a mode is most effective, and also to develop the corresponding software for these systems. The use of this circuit-design technique for reducing the switching factor is promising not only for $I^2L$ microcircuits, but also for other types of bipolar microcircuits. In this connection, the digital systems that utilize microcircuits based on bipolar transistors have power consumption approaching that of systems on complementary MDS transistors while retaining a considerable advantage in speed.

REFERENCES

1. N. A. Avayev, V. N. Dulin, Yu. Ye. Naumov, "Bol'shiye integral'nyye skhemy s inzhektsionnym pitaniyem" [Injection Coupled LSI Chips], Moscow, Sovetskoye radio, 1977.

2. V. Blatt, P. S. Walsh, L. W. Kennedy, "Substrate Fed Logic," IEEE, SC-10, No 5, 1975, p 336.

3. I. I. Shagurin, "Particulars of Designing Digital Devices Based on $I^2L$," MIKROELEKTRONIKA, Vol 7, No 3, 1978.

4. French Patent No 2,275,028, class H01L 27/06.

5. K. Kaneko, T. Okabe, M. Nagata, "Stacked $I^2L$ Circuit," ELECTRON LETT., Vol 12, No 10, 1976, p 249.

6. I. I. Shagurin, "Circuitry Principles, Element Base and Particulars of Designing Digital LSI Chips and Super-LSI Chips on Bipolar Transistors," MIKROELEKTRONIKA, Vol 7, No 2, 1978, p 99.



6610
CSO: 8144/0888

ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.382

# $I^2L$ QUASISTATIC MEMORY CELL

Kiev IZVESTIYA VUZOV: RADIOELEKTRONIKA in Russian Vol 21, No 12, 1978 pp 41-46

[Article by V. V. Barinov]

[Text] An examination is made of the particulars of operation of an injection-coupled quasistatic memory element containing two p-n-p and two n-p-n transistors. The area occupied by the memory cell is 2600 $\mu m^2$, recording time is 20 ns, and readout time is 10-20 ns. The results of machine calculation and experimentsl research confirm the workability and high energy characteristics of the memory cell.

Modern advances in development of bipolar circuits with 4 kbit dynamic storage capacity [Ref. 1-2] or even more [Ref. 3] are due primarily to the development of a variety of memory cells (MCs) with injection logic. At the present time injection MCs have been used as the basis for both static [Ref. 4] and dynamic [Ref. 5] integrated semiconductor storage circuit chips (ISSCCs). However, in the latter case [Ref. 5] the dynamic MC has only a formal, outward appearance of the injection structure, and only in recording the logical "1" does it operate in the state characteristic of injection circuits. A disadvantage of dynamic ISSCCs is the necessity for reconstructing (regenerating) information after definite time intervals that vary with ambient temperature. The known static injection MCs contain at least six transistors. Therefore a further increase in the information capacity of static ISSCCs is possible only by improving technology or by modifying conventional MCs.

This paper examines an injection MC that contains only four transistors with combined diffusion regions. In all modes of operation except readout, the described MC is a static unit. Destructive readout is possible; however, with limitation of the duration of the readout operation, information is self-restoring.

WORKING PRINCIPLES OF THE MEMORY CELL

The injection flip-flop on which all static MCs are based requires four transistors: two p-n-p and two n-p-n. If the emitters of current-setting p-n-p transistors are split, the flip-flop can be used for high-speed data recording [Ref. 6]. It turns out that current-setting p-n-p transistors are also convenient for use in data readout. The electric circuit of an injection MC of this type is shown in Fig. 1.

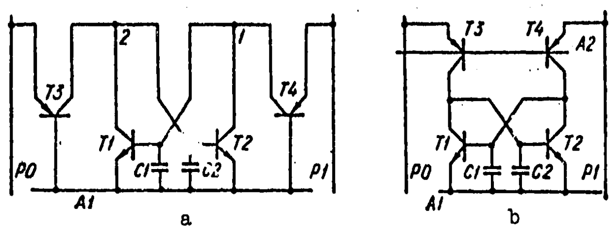



Fig. 1

Data storage. In this mode, approximately equal currents flow in bit lines P0 and P1 (Fig. 1a) so that one of the transistors T1 or T2 (say T1) is energized and saturated. Then the second transistor (T2) is switched off. In practice, when equal potentials $U_0$ are set on the bit lines of the MC in the storage mode, the flip-flop will have two stable states if in the equivalent circuit of the injection transistor [Ref. 7] $I_{ДК} > 0$, $I_{ДЭ} > 0$. This condition is met when

$$\alpha_N^n(I) > \frac{1}{2}.$$

Capacities $C_1$ and $C_2$, which are principally the barrier capacitances of the emitter junctions of transistors T1 and T2, have different charges:

$$Q_1 = \bar{C}_1 U_{эб\ нас}, \qquad Q_2 = \bar{C}_2 U_{кэ\ нас},$$

Here $U_{эб\ нас}$, $U_{кэ\ нас}$ are the emitter-base and collector-emitter voltages of the saturated transistor. The charge ratio

$$\frac{Q_1}{Q_2} = \frac{\bar{C}_1}{\bar{C}_2} \frac{U_{эб\ нас}}{U_{кэ\ нас}}$$

in practice with consideration of the voltage dependence of capacitances $C_1$ and $C_2$ is 10-20.

Recording. To energize transistor T2, it is first necessary to switch off transistor T1. This is accomplished by the collector current of T1 flowing through transistor T3. The current in line P1 at this time is low or nonexistent. Transistor T1 goes out of saturation, and the potential in node 2 increases. Then transistor T2 is put into saturation by the base current.

Readout. The information signal during readout is provided by the magnitude and direction of the current in the bit lines, which are due to the state of the MC. In the storage mode, charges $Q_1$ and $Q_2$ differ considerably. If transistor T1 is energized, the collector junction of transistor T4 is biased in the forward direction, while the collector junction of transistor T3 has practically zero bias. When the supply is switched off (the emitter junctions of T3 and T4 have reverse or zero biasing), capacitances $C_1$ and $C_2$ begin to recharge. Capacitance $C_1$ will discharge through the forward-biased p-n junctions: the emitter junction of transistor T1 and the collector junction of transistor T4, which are combined in the chip structure. Besides, capacitance $C_2$ will be charged through the collector junction of T1. A current due to charge $Q_1$ will flow through inversely connected transistor T4 in bit line P1. For the short times of the readout stage, the change in readout current can be approximately evaluated by the formula

$$I_{сч} = a\alpha_I^p \frac{\overline{C}_1 \varphi_T}{t},$$

Where $\alpha_I^p$ is the inverse current transfer coefficient of the p-n-p transistor, $a$ is some quantity that is constant for the MC and depends on the transfer coefficients and currents of the diodes in the injection structure model [Ref. 7]. There is practically no current in bit line P0. This difference in currents is utilized to identify the state of the MC and to determine the code of the stored information.

As will be shown below, readout of up to 100 ns duration does not lead to a change in the state of the flip-flop. Such a time segment is completely sufficient to ensure workability of the readout circuits and the entire ISSCC in the dynamic readout mode. With transition to the storage mode, equal currents are set in the emitters of transistors T3 and T4, the memory cell is returned to the initial state since the voltage (and charge) on capacitance $C_1$ is still greater than the voltage (and charge) on capacitance $C_2$. Transistor T1 goes into saturation, blocking transistor T2.

Shown in Fig. 1 are diagrams of the injection (a) and modified (b) quasistatic memory cells. A distinctive feature of the modified quasistatic MC is that the p-n-p transistors are made in a pocket insulated from the n-p-n transistors (Fig. 1b). The base potential of transistors T3 and T4 can be controlled by line A2, which is more convenient for the readout mode than with the injection MC (Fig. 1a). However, let us note that the area of the latter is much smaller.

## ANALYSIS OF THE READOUT MODE

The time constant of discharge of the capacitance through the p-n junction is determined by the expression [Ref. 8]

$$\tau = \varphi_T \frac{\ddot{C}}{I_{л0}},$$

[redacted]



where $I_{д0}$ is the initial current of the p-n junction. For real diodes, this quantity ranges from tens of milliseconds to tens of seconds. Thus we have confirmed the feasibility of data retention by the quasistatic injection MC during readout. Theoretically (if transistor T1 has been energized) the voltage across capacitance $C_2$ can never exceed that across $C_1$. However, in reality because of interference and technological scatter it is necessary to consider the possibility of false switching of the MC with transition from the readout mode to the storage mode.

In the storage mode, the potentials at node points of the flip-flop are respectively equal to

$$U_1 = U_{эо\,нас} \simeq U_0 + \varphi_т \ln\left(\alpha_N^p \frac{2-\alpha_I^n}{1-\alpha_N^n\alpha_I^n}\frac{I_{дк0}}{I_{дэ0}}\right),$$

$$U_2 = U_{кэ\,нас} \simeq \varphi_т \ln\left(\frac{2-\alpha_I^n}{2\alpha_N^n - 1}\frac{I_{дк0}}{I_{дэ0}}\right).$$

Here the $\alpha_{N,I}^{n,p}$ are current transfer coefficients, the superscript indicating the type of transistor, while the subscript indicates the method of measurement (normal or inverse mode). These expressions are derived for the case where equal potentials $U_0$ are set on the bit lines. Machine calculation has shown that 100 ns after the beginning of readout, the potential $U_1$ decreases by about 10%, while the potential $U_2$ increases by about 40%. Shown in Fig. 2 is the computer-calculated time dependence of readout current. Analysis shows that this quantity is not critical to the method of selecting the MC for line A1. When we consider the possible technological scatter by 15-20% in such parameters of the structure as the coefficients of current transfer, there is a corresponding change in readout current.

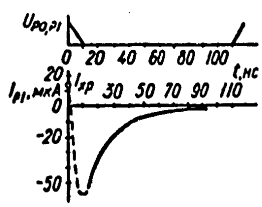



Fig. 2. мкА = μA; нс = ns; хр = storage

It can be approximately assumed that the change of charge in the load during readout is proportional to the change of charge on the storage capacitance with coefficient $\alpha_I^p$

$$\Delta Q_н \sim \alpha_I^p \Delta Q_1.$$

Then the relative change in voltage that is due to this charge on the load capacitance $C_H$ will be equal to

$$\frac{\Delta U_{Cн}}{\Delta U_{C1}} \sim \alpha_I^p \frac{C_1}{C_н}. \qquad (1)$$

Capacitances $C_1$ and $C_2$ can be increased by using the so-called "guard bands" [Ref. 9].

CONSTRUCTION OF THE ACCUMULATOR

The accumulator takes the form of a rectangular or square matrix. Bit lines P0 and P1 are joined for the elements of each column. Address line A1 is common to the MCs of each line. The topology of an accumulator fragment is shown in Fig. 3. With collector size of the n-p-n transistor of $10 \times 10$ μm and insulation of the p-n junction, the area of the accumulator per bit of information is 2600 $\mu m^2$. The use of dielectric insulation and more precise methods of combination can reduce the area of the MC to 1000 $\mu m^2$.

In an ISSCC with arbitrary sampling it is necessary to provide for access to an individual memory cell. Let us consider in more detail some of the peculiarities of choosing the MCs for a matrix of quasistatic elements.

Choosing the MCs for readout. A reduction of the potentials of the bit lines results in the beginning of discharging of the storage capacitance of all MCs of a given column. To prevent false readout it is necessary either to break the chain of discharge of the storage capacitances of unselected MCs, or to time-space the stages of readout of the false and useful signals. The latter can be realized for instance if discharge of the capacitances of unselected MCs takes place with a much shorter time constant

$$\tau^* = \varphi_T \frac{\tilde{C}}{I_{k0} + I_{kp}}.$$

Sampling during readout of the memory cell depicted in Fig. 1b can be implemented by a simpler method, using line A2.

Selection of MCs in recording. In the data recording mode, data recording current $I_{зап}$ flows through one of the selected bit lines. To prevent switching of all MCs in the given column, it is necessary that nearly all this current should be directed into a single MC. This can realized by reducing the input impedance of the selected memory cell. Fig. 4, showing

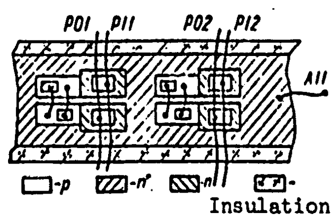



Fig. 3

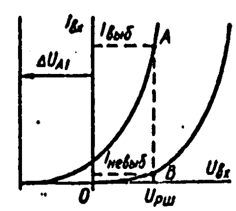



Fig. 4. $I_{вх}$ = input current
$I_{выб}$ = selected current
$I_{невыб}$ = unselected current
$U_{вх}$ = input voltage
$U_{рш}$ = bit-line voltage

the input characteristic of a quasistatic MC, illustrates the possibility of controlling input impedance by controlling the voltage through line A1. Computer calculation shows that in practice it is sufficient to lower the voltage of the address line by 0.3 V. By selecting the appropriate storage current flowing in the other bit line, or by disconnecting it, we prevent the possibility of switching unselected MCs.

At currents in the bit line of $I_{зап} = 1\text{-}5$ mA, data recording in the MC takes place in 20-30 ms. The main charge during readout flows in the load for 10-20 ns. Such characteristics enable us to design ISSCCs on quasistatic MCs with high speed. A memory circuit with 4096 bit capacity can be accommodated on a crystal with area of 20-25 mm$^2$.

FRAGMENT OF THE CONTROL CIRCUIT

As can be seen from expression (1), to get a fairly strong useful signal (50-200 mV) it is necessary to maximize the ratio $C_1/C_H$. The load capacitance associated with the bit line consists of the input capacitances of all MCs of the given column $nC_{вх\,зп}$, the input capacitance of the readout amplifier $C_{вх\,ус}$ and the parasitic capacitance of interconnections $C_M$:

$$C_н = nC_{вх\,зп} + C_{вх\,ус} + C_м.$$

$C_M$ in turn is comprised of the capacitances of interaction of the bit line with the nearby line on the same level of metallization, the lines of the other level going in the perpendicular direction, and the capacitances between the line and the substrate. For an accumulator column that contains 64 memory cells, calculation by the method described in Ref. 10 gives a value of $C_M \cong 2$ pF. The input capacitance of the memory cell can be reduced by reducing the capacitance of the emitter-base junction of the p-n-p transistor. To do this, the "n$^+$ guard band" must be at a certain distance from the emitter region of the p-n-p transistor. Contrariwise, for n-p-n transistors, overlapping the regions of base diffusion and the n$^+$ "band" enables an increase in storage capacitance $C_1$. Considering that the emitter junction of transistor T1 is forward-biased during data readout, while the emitter junctions of the p-n-p transistors are reverse-biased, we can get a readout signal with amplitude sufficient for a differential amplifier. Moreover, the accumulator can be broken up into sections to reduce the load capacitance.

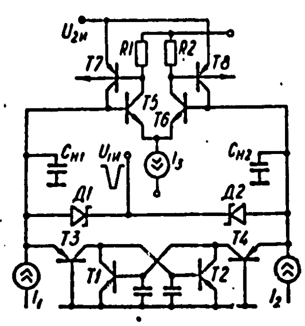



Fig. 5

One of the possible readout amplifier circuits is shown in Fig. 5. The circuit operates as follows. In the storage mode diodes Д1, Д2 and transistors T5-T8 are blocked. During data readout, current generators $I_1$ and $I_2$ are opened. Negative pulse $U_{1И}$ discharges the capacitances $C_H$ through diodes Д1 and Д2 to the initial level over the period of readout of false information. The readout signal charges one of the load capacitances, say $C_{H2}$, to a higher potential than $C_{H1}$. If the voltage difference on the capacitances exceeds the firing level, the differential amplifier on transistors T5 and T6 "reads out" the information as soon as current generator $I_3$ is energized. Transistors

T7 and T8 permit us to stabilize ("latch") the state of the amplifier during readout. The amplified signal is taken off from load $R_1$ and $R_2$.

CONCLUSION

An examination has been made of different modes of operation of a quasistatic $I^2L$ memory cell containing two n-p-n and two p-n-p transistors. For standard technology with insulation of the p-n junction, the MC occupies an area of 2600 $\mu m^2$. This enables accommodation of an ISSCC with 4096 bit capacity on a crystal with area of 20-25 $mm^2$. The speed of the MC during readout is 10-20 ns, and during recording -- 20-30 ns.

REFERENCES

1. L. Altman, "Preview of ISSCC Excites Designers," ELECTRONICS, Vol 45, No 26, 1975, p 50.

2. W. B. Sander, J. M. Early, "A 496x1. $I^3L$ Bipolar Dynamic RAM," IEEE ISSCC Dig. Techn. Pap., 1976, p 182.

3. L. Altman, "Five Technologies Squeezing more Performance from LSI Chips," ELECTRONICS, Vol 51, No 17, 1977, p 91.

4. L. Altman, "It's a User's Paradise," ELECTRONICS, Vol 51, No 2, 1977, p 81.

5. W. B. Sander et al., "Injection Logic Boosts Bipolar Performance While Dropping Cost," ELECTRONICS, Vol 51, No 17, 1977, p 107.

6. S. K. Wiedmann, "Injection-Coupled Memory: A High Density Static Bipolar Memory," IEEE, SC-8, No 5, 1973, p 332.

7. V. V. Barinov, V. Ya. Kontarev, V. I. Moshkin, A. A. Orlikovskiy, "Injection Coupled Integrated Logic and Memory Circuits" in "Mikroelementy i poluprovodnikovyye pribory" [Microelements and Semiconductor Devices], Moscow, Sovetskoye radio, No 1, 1976, p 108.

8. H. H. Henn, "Bipolar Dynamic Memory Cell," IEEE, SC-6, No 5, 1971, p 297.

9. V. V. Barinov, V. Ya. Kremlev, V. I. Moshkin, A. A. Orlikovskiy, "Injection Coupled Integrated Circuits," ZARUBEZHNAYA ELEKTRONNAYA TEKHNIKA, Central Scientific Research Institute of Electronics, No 9, 1973, p 3.

10. "Spravochnik po konstruirovaniyu EVM" [Handbook on Computer Design], edited by S. A. Mayorov, Moscow, Sovetskoye radio, 1975.



6610
CSO: 8144/0885

ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.391.2

## THE RELATIONSHIP BETWEEN SEA WAVE SPECTRA AND THE SPECTRAL AND CORRELATION CHARACTERISTICS OF A REFLECTED RADIO SIGNAL

Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian No 12, Dec 78 pp 2511-2518

/Article by A. A. Garnaker'yan, signed to press 21 Mar 77/

/Text/ Within the framework of Kirchhoff's theory it has been shown that in the shortwave spectrum for small viewing angles and wide antenna radiation patterns, a normalized, three-dimensional, correlation function of the reflected signal at small Rayleigh variables coincides with a normalized, three-dimensional, correlation function of the sea surface.

The relationship has been established between the frequency spectrum of sea waves and the envelope spectrum of a reflected shortwave signal, originally beamed from the air.

The results are presented of experiments to determine by aerial radar the frequency spectrum of sea waves and the angular distribution function of wave energy. The experimental results correspond well with the derived data and demonstrate the possibility of determining sea wave spectra by aerial radar with adequate precision.

### Introduction

An important national economic and scientific problem today is the development of telemetric methods to measure sea wave parameters. A two-dimensional spectrum $S_{\text{в}}(\omega_{\text{в}}, \alpha)$ best describes sea wave phenomena. The analytic expression for the two-dimensional spectrum is usually written as the product /1/

$$S_{\text{в}}(\omega_{\text{в}}, \alpha) = S_{\text{в}}(\omega_{\text{в}})\varphi(\alpha), \tag{1}$$

where $S_{\text{в}}(\omega_{\text{в}}) = \int_{-\pi/2}^{\pi/2} S_{\text{в}}(\omega_{\text{в}}, \alpha)\, d\alpha$ is the frequency spectrum; $\varphi(\alpha)$ —the angular distribution function of wave energy:

(2) $\varphi(\alpha)=p|\cos^n\alpha|; \quad -\frac{\pi}{2}\leqslant\alpha\leqslant\frac{\pi}{2};$

p—normalizing multiplier:

(3) $$p=\frac{1}{\int\limits_{-\pi/2}^{\pi/2}\cos^n\alpha}=\frac{\Gamma\left(\frac{n}{2}+1\right)}{\sqrt{\pi}\,\Gamma\left(\frac{n+1}{2}\right)}.$$

$\Gamma(x)$—gamma function; n depends on the intensity and character of sea wave phenomena.

We will examine the possibility of determining aerially a sea wave spectrum through the spectral and correlation characteristics of a shortwave radio signal.

1. The relationship between the three-dimensional correlation function of a reflected signal and the three-dimensional correlation function of the sea surface

The problem of a three-dimensional correlation of a electromagnetic field after passage through a chaotic nonhomogeneous deflector has been examined in [2].

References [3,4] used the perturbation method to solve the problem of three-dimensional correlation ratios for sound and electronmagnetic wave reflection from a statistically rough surface with large and small irregularities, when the wave phenomena were emitted from a point source.

To amplify and develop the results obtained in [2-4] in solving the opposite problem of scattering, which consists of determining the correlation function of a surface according to the three-dimensional correlation function of a reflected wave, we will consider the width of the radiation pattern of actual emitters, the three-dimensionality and anisotropy of the sea surface.

From point $A(0,0,z_0)$ (Fig. 1) the surface is exposed to a monochromatic electromagnetic wave. For viewing angles close to normal ($\beta<30°$), one may ignore the contribution of small irregularities in the reflected signal and consider only the reflection from the basic surface configuration.

Following [5, 6] and using Kirchhoff's method, we will assume that the irradiated surface, expressed by $z=h(x,y)$, is smooth and gently sloping, i.e., the conditions [5, 6]

$$\mathrm{tg}\,\gamma_{hx}<0{,}2, \quad \mathrm{tg}\,\gamma_{hy}<0{,}2$$

and

$$4\pi r_x \cos\psi \gg \lambda, \quad 4\pi r_y \cos\psi \gg \lambda,$$

are met, where $\gamma_{hx}$ and $\gamma_{hy}$ are the root-mean-square slope angles; $r_x$ and $r_y$—the local radii of the surface curvature in the direction of the coordinate axes 0x and 0y; $\psi$ —the angle between the direction of irradiation and the normal to the surface at point M (Fig. 1); $\lambda$ —the length of the radiated wave.

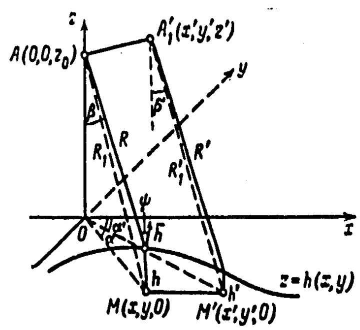



Figure 1. Geometry of the Problem

The plane z = 0 is the mean for the surface z = h(x,y). For small viewing angles ($\beta<30°$) the complex stress amplitude of the signal at the output of the receiving antenna may be written as [7, 8]

$$\dot{u}(A)=\frac{ikQ_1\dot{F}_0}{2\pi}\iint\limits_{S_1} G^2(\alpha,\beta)R_1^{-2}\exp[-2ik(R_1-h\cos\beta)]\,dx\,dy, \tag{4}$$

where $k=2\pi/\lambda$; $Q_1=\sqrt{P_0G_0A_{э\phi}R_{np}/2\pi}$; $P_0$ is the power emitted by the antenna; $G_0$—antenna gain factor; $A_{э\phi}$ —effective antenna area ($A_{э\phi}=G_0\lambda^2/4\pi$); $R_{np}$ —effective resistance of the receiving antenna; $\dot{F}_0=1-(2/\sqrt{\dot{\varepsilon}})$; $\dot{\varepsilon}$ —relative complex permittivity of water; $G(\alpha,\beta)$ —a function describing the radiation pattern of the antenna; $\alpha, \beta, R, h$ as shown in Fig. 1; $S_1$ —the projection of an irradiated surface area on the mean plane.

Axisymmetric antennae, whose radiation pattern axes were directed vertically downward ($\beta_1=0$) were used for reception and transmission.

The Gaussian equation [7]

$$(5)\qquad G(\alpha, \alpha)=\exp\left[-\frac{1{,}38}{\theta_a^2 z_0^2}(x^2+y^2)\right],$$

is used to describe the radiation patterns of the antennae, where $\theta_a$ is the width of the antenna radiation pattern at half power.

The existence of intervals of quasistability and sections of quasi-homogeneity, as well as the suitability of the ergodic theory [1] were assumed for the sea waves.

The correlation function of the reflected signal at separate points A and A' is derived from [2]

$$(6)\qquad R_0(A, A')=\overline{[\dot u(A)-\overline{\dot u(A)}][\dot u^*(A')-\overline{\dot u^*(A')}]},$$

where $\overline{\dot u(A)}$ is the mean value of complex stress amplitude; $\overline{\dot u^*(A)}$ —a value, closely associated with $\dot u(A)$. The bar above in (6) indicates the statistical averaging of the random variable h for an ensemble of realizations.

According to experimental and theoretical results the probability density of sea wave rises h follows the norm when the mean value equals zero ($\bar h=0$) [1].

Using (4) and assuming a normal distribution of rises h, formula (6) becomes

$$(7)\qquad R_0(A, A')=\left(\frac{kQ_1|F_0|}{2\pi}\right)^2\iint_{s_0} G^2(\alpha,\beta)R_1^{-2}\,dx\,dy\iint_{s_0} G^2(\alpha',\beta')R_1'^{-2}\times$$

$$\times\exp[-2ik(R_1-R_1')]\{\exp[-2k^2\sigma_h^2(\cos^2\beta+\cos^2\beta'-2\rho_h(\Delta x,\Delta y)\times$$
$$\times\cos\beta\cos\beta')]-\exp[-(2k^2\sigma_h^2\cos^2\beta+2k^2\sigma_h^2\cos^2\beta')]\}\,dx\,dy,$$

where $\rho_h(\Delta x, \Delta y)$ is the normalized correlation function of the surface; $\sigma_h$ —the standard deviation of surface rises.

We will assume that the surface correlation radii $l_{hx}$ and $l_{hy}$ are significantly smaller than the radius of the region, required for reflection. Thus, in formula (7) it may be assumed that $G^2(\alpha', \beta')=G^2(\alpha, \beta)$, $R_1'^{-2}=R_1^{-2}$, $\cos\beta'=\cos\beta$, while the limits of integration for the internal integral are expanded to infinity.

In the case of small surface irregularities $[(2k\sigma_h)^2<1;\ \sigma_h/\lambda<1/16]$, as a result of noncomplex, but sufficiently cumbersome transformations, we obtain [9]

$$R_0(A,A')=\left(\frac{k^2\sigma_h\theta_a Q_1|F_0|}{\sqrt{5{,}5\pi}\,z_0}\right)^2\exp[-(2k\sigma_h)^2+2ik\Delta z]\times$$
$$\times\int_{-\infty}^{\infty}\int\rho_h(\Delta x,\Delta y)\exp\left\{-\frac{k^2\theta_a^2}{5{,}5}[(\Delta x_1-\Delta x)^2+(\Delta y_1-\Delta y)^2]\right\}\times$$
$$\times\exp\left\{\frac{ik}{z_0}[(\Delta x_1-\Delta x)^2+(\Delta y_1-\Delta y)^2]\right\}. \quad (8)$$

To compute the integral in (8) one has to define specifically the form of the three-dimensional correlation function of the surface $\rho_h(\Delta x, \Delta y)$. For three-dimensional anisotropic sea waves the normalized spatial correlation function appears as

$$\rho_h(\Delta x,\Delta y)=\exp\left[-\left(\frac{\Delta x^2}{l_{hx}^2}+\frac{\Delta y^2}{l_{hy}^2}\right)\right]\cos\frac{2\pi}{\Lambda_{hx}}\Delta x\cos\frac{2\pi}{\Lambda_{hy}}\Delta y, \quad (9)$$

where $l_{hx}$ and $l_{hy}$ are correlation radii, and $\Lambda_{hx}$ and $\Lambda_{hy}$ mean lengths of sea waves in the direction of coordinate axes Ox and Oy (Fig. 1). The correlation function (9) corresponds to the spectral density, which adequately approximates the spectral density of sea waves near the relative maximum [10].

By putting (9) into formula (8), assuming $k/z_0 \ll 1$, and holding the intensity constant, we derive, deleting intermediary calculations, the final expression for a standard three-dimensional correlation function of the complex amplitude of a reflected radio wave

$$\dot\rho_0(A,A')=\frac{R_0(A,A')}{I(A)}=\exp(2ik\Delta z)\times$$
$$\times\exp\left[-\left(\frac{\Delta x_1^2}{l_{1x}^2}+\frac{\Delta y_1^2}{l_{1y}^2}\right)\right]\cos\frac{2\pi}{\Lambda_{1x}}\Delta x_1\cos\frac{2\pi}{\Lambda_{1y}}\Delta y, \quad (10)$$

where

$$l_{1x}=l_{hx}\sqrt{1+\frac{5{,}5}{(\theta_a/\theta_{px})^2}};\quad l_{1y}=l_{hy}\sqrt{1+\frac{5{,}5}{(\theta_a/\theta_{py})^2}};$$
$$\Lambda_{1x}=\Lambda_{hx}\left[1+\frac{5{,}5}{(\theta_a/\theta_{px})^2}\right];\quad \Lambda_{1y}=\Lambda_{hy}\left[1+\frac{5{,}5}{(\theta_a/\theta_{py})^2}\right];$$

$\theta_{0x}$ and $\theta_{py}$ are the widths of the back scattering pattern in the Ox and Oy directions; $\theta_{px}=1/kl_{hx}$; $\theta_{py}=1/kl_{hy}$. From (10) it follows that for random relations between the width of the radiation pattern and the width of the back scattering pattern $\theta_a/\theta_{px}$ and $\theta_a/\theta_{py}$, the transverse correlation function of the complex amplitude of a reflected signal (for $\Delta z = 0$), in general, does not coincide with the surface correlation function.

For broad antennae, i.e., when the conditions $(kl_{hx}\theta_a)^2 \gg 5{,}5$ and $(kl_{hy}\theta_a)^2 \gg 5{,}52$, are fulfilled, the expression for the normalized transverse spatial correlation function of the complex amplitude of a reflected signal becomes

$$\rho_c(A, A') = \exp\left[-\left(\frac{\Delta x_1^2}{l_{hx}^2} + \frac{\Delta y_1^2}{l_{hy}^2}\right)\right] \cos\frac{2\pi}{\Lambda_{hx}} \Delta x_1 \cos\frac{2\pi}{\Lambda_{hy}} \Delta y. \tag{11}$$

Thus, in this case the standard correlation function of the complex amplitude of a reflected signal agrees with the normalized correlation function of the surface ($\rho_c = \rho_h$). Derivation (11) agrees fully with the result obtained in [4] for a point radiation source. For a sea surface the shortwave band well suits small irregularities ($\sigma_h/\lambda < 1/16$). In this wave band it is also easy to achieve an antenna with a wide radiation pattern.

Thus, the use of shortwave radio waves makes it possible, in principle, to solve the reverse problem of determining the three-dimensional correlation function of a sea surface from the three-dimensional correlation function of a reflected signal.

However, the aerial determination of the three-dimensional correlation function of a reflected signal presents significant technical problems. Therefore, from a technical point of view it is useful to determine the autocorrelation function or the envelope spectrum of a reflected signal.

2. The relation between the sea wave spectrum and the envelope spectrum of a reflected signal for a surface aerially irradiated

With the reception of reflected signals by a single receiving antenna and an aerial flight speed in the horizontal plane of V, using the results derived above and substituting in (8)

$$\Delta x_1 = V_x \tau \quad \text{and} \quad \Delta y_1 = V_y \tau, \tag{12}$$

one can show that the expression for a normalized autocorrelation function of a reflected signal becomes

$$\rho_c(\tau) = \exp\left[-\left(\frac{V_x^2\tau^2}{l_{hx}^2} + \frac{V_y^2\tau^2}{l_{hy}^2}\right)\right] \times \cos\frac{2\pi}{\Lambda_{hx}} V_x\tau \cos\frac{2\pi}{\Lambda_{hy}} V_y\tau \cos\omega_0\tau, \tag{13}$$

where $V_x$ and $V_y$ are the horizontal velocity components of flight in the direction of the coordinate axes; $\tau$ —time; $\omega_0$ —angular frequency of the reflected signal.

In investigating sea waves from the air it is useful to examine a section of the surface correlation function $\rho_h(\Delta x, \Delta y)$ in the direction of flight $\alpha-\rho_{h\alpha}(\Delta r)$, where $\Delta r=\sqrt{\Delta x^2+\Delta y^2}$.

In this case, for a uniform surface, using the results derived above, we will express the autocorrelation function for envelopes of the reflected signal as

$$\rho_{co}(\tau)=\exp\left(-\frac{V_\alpha^2\tau^2}{l_{h\alpha}^2}\right)^2\cos\frac{2\pi}{\Lambda_{h\alpha}}V_\alpha\tau, \tag{14}$$

where $V_\alpha$, $l_{h\alpha}$, $\Lambda_{h\alpha}$ are the flight velocity, the correlation radius, and wave length in the direction of flight $\alpha$, respectively.

In the shortwave range, given $\sigma_h/\lambda\leqslant{}^1/_{16}$ , the energy of a coherent (fixed) component of a reflected signal $P_k$ exceeds the energy of a noncoherent (fluctuating) component $\bar{P}_n$ $(\bar{P}_k/\bar{P}_n>3)$ [12]. In this case the normalized correlation function of a reflected signal envelope at linear detector output approximately equals the envelope of the normalized correlation function of an input signal $\rho_{co}$ $(\rho_n(\tau)\simeq\rho_{co}(\tau))$.

Assuming $\rho_n(\tau)\simeq\rho_{co}(\tau)$ and using (14), one can establish the relation between the surface wave number $S_x(\chi_\alpha)$ in the $\alpha$ direction and the normal spectrum of the reflected signal envelope $S_n{}^n(\omega_c)$:

$$S_x(\chi_\alpha)=\sigma_h{}^2V_\alpha S_n{}^n(\chi_\alpha V_\alpha), \tag{15}$$

where

$$\chi_\alpha=\frac{2\pi}{\Lambda_{h\alpha}};\quad \omega_c=\chi_\alpha V_\alpha.$$

The transition from a frequency wave spectrum to a surface wave number spectrum can be accomplished by the formula in [1]

$$S_x(\chi_0)=\frac{1}{2}\sqrt{\frac{g}{\chi_0}}S_s(\sqrt{\chi_0 g}), \tag{16}$$

where $\chi_0$ is the surface wave number in a direction, coinciding with the general direction of sea wave propagation; $g$—acceleration due to gravity; $\omega_s=\sqrt{\chi_0 g}$.

Using (15) and (16) we derive the relation between the sea wave frequency spectrum and the spectrum of the reflected wave envelope:

$$S_{\text{в}}(\omega_{\text{в}}) = \frac{2\sigma_h^2 V_0 \omega_{\text{в}}}{gp} S_c^{\text{н}}\left(\frac{\omega_{\text{в}} V_0}{g}\right), \tag{17}$$

where $V_0$ represents flight velocity in the direction of sea wave propagation; $\omega_{\text{в}} = \sqrt{\omega_c g / V_0}$.

## 3. Experimental results

Aerial experiments were conducted over the Black Sea between 1970-1973 and in 1976 with the aid of a specially developed shortwave radar, operating at a wave length of $\lambda = 10$ м [11], [12]. The technical data obtained from this instrument are presented in [11, 12], and a functional schematic in [11].

Flights with the radar on board a plane produced at various altitudes (500-4000 m), for various speeds (250-500 km/hr), and in various directions a relatively central direction of sea wave propagation. The area of the sea undergoing study was 15-20 km from shore, and 150-200 m deep. In all more than 50 flights were made. A loop oscillograph was used to record on board the plane the reflected signal envelopes at receiver output. A GM-16 wave recorder, located on the sea surface [11] and activated from the plane, recorded the height of the waves.

The variance in sea surface height $\sigma_h^2$ was measured simultaneously with the radar recording of the reflected signal envelopes in the shortwave band. A functional diagram of the device used to measure $\sigma_h^2$ and the method used to take measurements are presented in [11], and the results of the measurements can be found in [11, 12].

The sea wave frequency spectra $S_{\text{в}}(f_{\text{в}})$ were calculated according to wave recordings obtained from the GM-16 wave recorder, while the normal envelope spectra $S_c^{\text{н}}(f_c)$ from the reflected signal envelope recordings. The normal spectra of reflected signal envelopes were recomputed by formula (15) into surface wave number spectra and through formula (17) into frequency spectra of sea wave rises. The frequency spectra of sea surface rises, obtained from the wave graphs made by the GM-16 wave recorder, were compared with the spectra of sea surface rises, calculated from the experimental spectra of reflected signal envelopes with the aid of formula (17).

A comparative analysis was performed on more than 30 spectra, which showed that they coincided quite well.

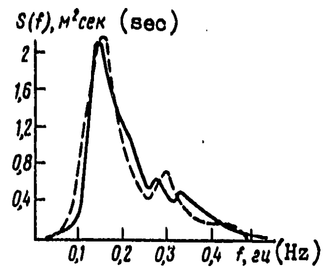



Fig. 2. Frequency spectrum of sea swell

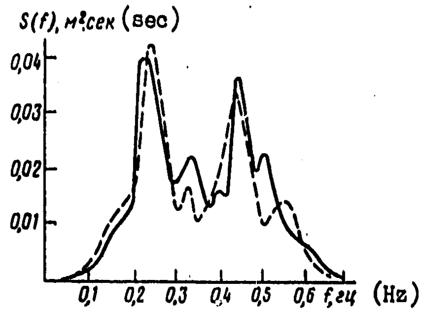



Fig. 3. Frequency spectrum of mixed waves

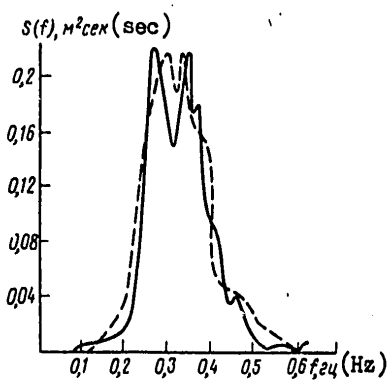



Fig. 4. Frequency spectrum of wind driven waves

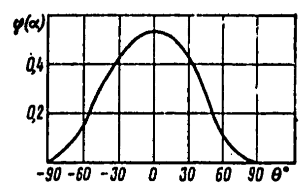



Fig. 5. Angular distribution of wave energy

Figures 2-4, for example, show the frequency spectra of sea surface rises, $S_{\bullet}(f_{\bullet})$ ($f_{\bullet}=\omega_{\bullet}/2\pi$), derived from wave recordings, made from the GM-16 wave recorder (solid lines), and the spectra of sea surface rises, computed from reflected signal envelope recordings (broken line). Fig. 2 shows the spectrum of a sea swell; Fig. 3—a combination of waves; Fig. 4—wind driven wave.

From the radar data on the wave number spectra $S_1(\chi_1)$ in the $\alpha$ direction were computed angular distribution functions of wave energy $\varphi(\alpha)$. Fig. 5 shows the function $\varphi(\alpha)$, obtained by radar for swell, whose frequency spectrum is presented in Fig. 2. According to experimental findings the degree of the cosine n of the angular distribution function of wave energy lies within the range n=1.3-6. With an increase in wave intensity (wave height) the degree of the cosine n increases.

The experimental results showed that it is possible in principle to determine a two-dimensional spectrum of sea waves and a description of sea waves by aerial radar in the shortwave range.

## BIBLIOGRAPHY


1. Krylov, Yu. M. "Spektral'nyye metody issledovaniya i rascheta vetrovykh voln" /Spectral Methods of Studying and Computing Wind Waves/, Gidrometeoizdat, 1966.

2. Rytov, S. M. "Vvedeniye v statisticheskuyu radiofiziku" /Introduction to Statistical Radio Wave Physics/, Izd. Nauka, 1966.

3. Gulin, E. P. IZV. VUZOV MVSSO SSSR (RADIOFIZIKA) /Bulletin of the VUZ's of the Ministry of Higher and Secondary Special Education USSR (Radio Wave Physics)/, Vol 6, No 6, 1963.

4. Bass, F. G.; Fuks, I. M. "Rasseyaniye voln na statisticheski nerovnoy poverkhnosti" /Dispersion of Waves on a Statistically Rough Surface/, Izd. Nauka, 1972.

5. Brekhovskikh, L. M. ZhETF /Journal of Experimental and Theoretical Physics/, Vol 3, No 9, 1952.

6. Isakovich, M. A. ZhETF, Vol 3, No 9, 1952.

7. Zubkovich, S. G. "Statisticheskiye kharakteristiki radiosignalov, otrazhennykh ot zemnoy poverkhnosti" /Statistical Characteristics of Radio Wave Signals, Reflected from the Earth's Surface/, Izd. Sovetskoye radio, 1968.

8. Zhukovskiy, A. P. IZV. VUZOV MVSSO SSSR (RADIOFIZIKA), Vol 12, No 4, 1969.

9. Gradshteyn, I. S.; Ryzhik, I. M. "Tablitsy integralov, summ, ryadov i proizvedeniy" /Tables of Integrals, Sums, Series, and Products/, Izd. Nauka, 1971.

10. Krasyuk, A. P.; Rozenberg, V. N. "Korabel'naya radiolokatsiya i meteorologiya" /Marine Radiolocation and Meteorology/, Izd. Sudostroyeniye, 1970.

11. Garnaker'yan, A. A.; Sosunov, A. S.; Lobach, V. T., et al. "The Problem of Measuring the Height of Sea Waves by Radiolocation," in "Nekontaktnyye metody izmereniya okeanograficheskikh parametrov" /Reports of the All Seminar entitled "Indirect Methods of Measuring Oceonographic Parameters"/, Gidrometeoizdat, 1975.

12. Garnaker'yan, A. A.; Sosunov, A. S. RADIOTEKHNIKA I ELEKTRONIKA, Vol 21, No 11, 1976, p 2300.



8506
CSO: 1870

ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.391.2

TRANSFORMATION OF THE SUM OF TWO PERIODIC PHASE MODULATED SIGNALS BY A DIGITAL SIDE LOBE CANCELLATION FILTER

Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian No 12, Dec 78 pp 2519-2524

/Article by V. P. Ipatov, Yu. A. Kolomenskiy, and Yu. K. Shumilov, signed to press 31 Mar 77/

/Text/ A digital filter for canceling side lobes of a periodic output signal is analyzed. It is shown that the interference of two signals at input into a linear digital filter is not accompanied by the appearance of new side lobes at filter output. Quantitative relationships are established which connect the quantization increment by level with the efficiency coefficients of digital processing.

With respect to periodic phase modulated (pm) signals, as described in /1/, it is possible in principle to cancel completely all side lobes of a periodic cross-correlation function (PCCF) of a signal. The conditions necessary to create a filter for side lobe cancellation of the PCCF (more simply SLCF) and the relations which determine its structure are derived in /2/. One promising SLCF, apparently, has a digital configuration. In particular, Fig. 1 presents a block diagram of a transverse /3/ digital SLCF (DSLCF) for a binary pm-signal with a period of N digits. In the diagram the digitizer (D) converts the analog input into a discrete sequence of analog readings, within the interval $\tau_c$, where $\tau_0$ is the pm-signal digit length; the analog-to-digital converter (ADC) quantifies this sequence according to a given standard, while the weighting factors $y_i$, $i = \overline{0, N-1}$, selected according to /2/, weight the ADC output and N - 1 delay elements (DE) in $\tau_c$ prior to delivery to the accumulator. Without any loss to generality, one may assume that the weighting factors $y_i$ satisfy the normalizing condition $\sum_{i=1}^{N} y_i^2 = 1$. Since the SLCF is designed to resolve periodic pm-signals, overlapping in time /2/, and the introduction of an ADC makes the device nonlinear, the effect of the ADC on the resolution values deserves special attention. This article analyzes in detail the effect that the superpositon of two periodic binary pm-signals, in combination with shot noise, has on a DSLCF.

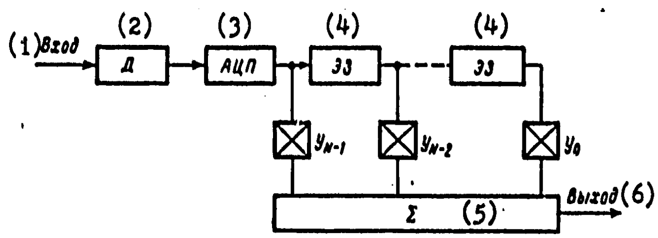



Figure 1

Key:

1. Input
2. D
3. ADC
4. DE
5. Accumulator
6. Output

Let $\varphi=f(\xi)$ be the ADC characteristic, into whose input goes the digital-to-analog pulse train of the form

$$\xi_j=p_1x_{((j))}+p_2x_{((j+k))}+n_j, \quad j=\ldots,-1,0,1,2,\ldots,$$

where $((j))=j(\mathrm{mod}\,N)$, $0\leq((j))\leq N-1$, $x_i=\pm1$—complex amplitudes of a binary periodic pm-signal, k—shift of the second pm-signal relative to the first in digit number, $n_j$—reading of stationary shot noise with zero mean, unit variance, probability density W(n) and time correlation no greater than $\tau_t$; $p_r$, r = 1, 2—ratio of the instantaneous value of the r-th signal at the moment of quantization to the actual noise value, $-\infty<p_r<\infty$.

Let, also,

$$\psi_i(q)=\overline{f^i(\xi)}=\int_{-\infty}^{\infty} f^i(\xi)W(\xi-q)d\xi$$

—i-th initial moment of random value at ADC output, when at the input of the latter the $\xi$ equals the sum of the fixed term q and the noise value $n$, $\xi=q+n$.

The result of the analog-to-digital transformation of the input process can be represented by a sequence of numbers $\varphi_j=f(\xi_j)$, $j=\ldots,-1,0,1,\ldots$, whereas the i-th initial moment of the j-th element of this sequence

$$\overline{\varphi_j^i}=\overline{f^i(\xi_j)}=\psi_i(p_1x_{((j))}+p_2x_{((j+k))})$$

due to the periodicity of the signal and stability of noise periodically depend on j, i.e., $\overline{\varphi_j^i}=\overline{\varphi^i_{((j))}}$.

We will introduce the following notation: $Y=(y_0, y_1, \ldots, y_{N-1})'$ —N-dimensional vector matrix of the weighting coefficients of the DSLCF (filter vector), $\bar{F}=(\varphi_0, \varphi_1, \ldots, \bar{\varphi}_{N-1})'$ —N-dimensional matrix of mean values of readings at ADC output, $D=\|d_{ij}\| - N\times N$ matrix of the linear operator of the cyclical shift, whose elements above the diagonal and lower left element equal 1, all others—0.

Then for the mean value of the j-th reading at DSLCF output we obtain

$$Z_j=(D^jF)'Y$$

or due to the orthogonality of matrix D and the equality $(D^j)'=D^{-j}$, resulting from it,

$$(1) \qquad Z_j=F'D^{-j}Y.$$

Given an odd ADC characteristic and symmetrical noise the function $\psi_1(q)$ is odd; therefore, the components $\varphi_l$, $l=\overline{0, N-1}$ of vector $F$ with respect to $x_l=\pm 1$ take on only four possible values

$$(2) \qquad \varphi_l=\begin{cases} x_l\psi_1(p_1+p_2), & x_l=x_{((l+k))},\\ x_l\psi_1(p_1-p_2), & x_l=-x_{((l+k))}.\end{cases}$$

Rewriting (2) as $\varphi_l=\frac{1}{2}[(x_l+x_{((l+k))})\psi_1(p_1+p_2)+(x_l-x_{((l+k))})\psi_1(p_1-p_2)]$,

for vector $F$ we obtain

$$F=\frac{1}{2}\psi_1(p_1+p_2)(X+D^kX)+\frac{1}{2}\psi_1(p_1-p_2)(X-D^kX),$$

where $X=(x_0, x_1, \ldots, x_{N-1})'$—N-dimensional signal vector-matrix. As long as vector Y must be selected from the condition [2]

$$XD^{-j}Y=\begin{cases} 0, & j\neq 0 \pmod N,\\ \eta\sqrt{N}, & j=0 \pmod N,\end{cases}$$

where $\eta$ characterizes the linear SLCF loss relative to a matched filter, then for (1) we have

$$(3) \qquad Z_j=\begin{cases} 0, & j\neq 0,\ k \pmod N,\\ \frac{1}{2}\eta\sqrt{N}[\psi_1(p_1+p_2)+\psi_1(p_1-p_2)]; & j=0 \pmod N,\\ \frac{1}{2}\eta\sqrt{N}[\psi_1(p_1+p_2)-\psi_1(p_1-p_2)], & j=k \pmod N.\end{cases}$$

Applying analogous arguments, one can obtain the following expression for the variance of the j-th reading at DSLCF output:

$$(4)\qquad D\{Z_j\}=\frac{1}{2}[\psi_2(p_1+p_2)+\psi_2(p_1-p_2)-\psi_1^2(p_1+p_2)-$$

$$-\psi_1^2(p_1-p_2)]+\frac{1}{2}[\psi_2(p_1+p_2)-\psi_2(p_1-p_2)-\psi_1^2(p_1+p_2)+$$

$$+\psi_1^2(p_1-p_2)]\sum_{i=0}^{N-1}x_i x_{((i+k))}y^2_{((i+j))}.$$

The arrangement in (3), (4) $p_2=0$ yields obvious expressions for the mean value and variance at DSLCF output given only a single input signal:

$$\bar{Z}_j=0,\ j\neq 0\,(\mathrm{mod}\ N);$$
$$\bar{Z}_j=\eta\sqrt{N}\psi_1(p_1),\ j=0\,(\mathrm{mod}\ N);$$
$$D\{Z_j\}=\psi_2(p_1)-\psi_1^2(p_1).$$

Relation (4) shows that the introduction of an ADC with odd characteristic into the SLCF in processing the superposition of two time variant binary periodic pm-signals forces the variance at filter cuput to depend on both the reading number j and the signal levels $p_1$, $p_2$. What is more, as is apparent from (3), the signal levels affect the mean values of the main lobes of the SLCF. At the same time (see (3)) the mean values of the side lobes remain equal to zero independent of signal intensity.

We shall find quantitative estimates of these effects for equidistant ADC with characteristic form

$$(5)\qquad f(\xi)=m,\quad \left(m-\frac{1}{2}\right)\Delta<\xi\leqslant\left(m+\frac{1}{2}\right)\Delta,$$

$$m=\ldots,-1,0,1,2,\ldots,$$

where $\Delta$ is the quantization increment by level, normalized to the actual value of the input noise.

By writing $f(\xi)$ as

$$f(\xi)=\sum_{m=0}^{\infty}\Delta\left\{h\left[\theta-\Delta\left(m+\frac{1}{2}\right)\right]-h\left[-\theta-\Delta\left(m+\frac{1}{2}\right)\right]\right\},$$

where

$$h(x)=\begin{cases}0, & x<0,\\ \frac{1}{2}, & x=0,\\ 1, & x>0,\end{cases}$$

and averaging, assuming normal noise, we obtain

$$(6)\qquad \psi_1(q)=\Delta\sum_{m=0}^{\infty}\left\{F\left[q-\Delta\left(m+\frac{1}{2}\right)\right]+F\left[q+\Delta\left(m+\frac{1}{2}\right)\right]\right\},$$

where $F(x)=(1/\sqrt{2\pi})\int_0^x \exp(-t^2/2)\,dt$ is the probability function. Another useful formulation of $\psi_1(q)$ can be obtained by expanding the quantization error into a Fourier series [4]

$$(7)\qquad \xi-f(\xi)=\sum_{m=1}^{\infty}\frac{\Delta}{\pi m}(-1)^m\sin\frac{2\pi m}{\Delta}\xi.$$

Averaging, we obtain

$$(8)\qquad \psi_1(q)=q+\sum_{m=1}^{\infty}\frac{\Delta}{\pi m}(-1)^m\sin\frac{2\pi m}{\Delta}q\exp\left[-2\left(\frac{\pi m}{\Delta}\right)^2\right].$$

For $\psi_2(q)-\psi_1^2(q)$ one may write

$$(9)\qquad \psi_2(q)-\psi_1^2(q)=\sum_{k=-\infty}^{\infty}\{\Delta k-\psi_1(q)\}^2\left\{F\left[q-\Delta\left(k-\frac{1}{2}\right)\right]\right.$$
$$\left.-F\left[q-\Delta\left(k+\frac{1}{2}\right)\right]\right\}.$$

Formulas (6) or (8) and (9) make it possible with (3), (4) to compute the mean values of the main lobes and the variance at DSLCF output. In particular, for the mean value of the main lobe of the first signal we obtain from (6), (3)

$$(10)\qquad Z_0=\frac{\Delta\eta\sqrt{N}}{2}\sum_{m=0}\left\{F\left[p_1+p_2-\Delta\left(m+\frac{1}{2}\right)\right]\right.$$
$$+F\left[p_1+p_2+\Delta\left(m+\frac{1}{2}\right)\right]+F\left[p_1-p_2-\Delta\left(m+\frac{1}{2}\right)\right]$$
$$\left.+F\left[p_1-p_2+\Delta\left(m+\frac{1}{2}\right)\right]\right\}$$

or from (8), (3)

$$(11)\qquad Z_0=\eta\sqrt{N}\left\{p_1+\frac{\Delta}{\pi}\sum_{m=1}^{\infty}\frac{(-1)^m}{m}\exp\left[-2\left(\frac{\pi m}{\Delta}\right)^2\right]\right.$$
$$\left.\times\sin\frac{2\pi m}{\Delta}p_1\cos\frac{2\pi m}{\Delta}p_2\right\}.$$

Of special interest is the situation in which one of the signals, for example, is weak. Assuming $p_1 \ll 1$ and restricting oneself in expansions (10), (11) in the $p_1$ rows only to members with first degree $p_1$, we have

$$(12)\qquad Z_0 \simeq \frac{\Delta\eta\sqrt{N}}{\sqrt{2\pi}} p_1 \sum_{m=0}^{\infty}\left\{\exp\left[-\frac{\left(p_2-\Delta\left(m+\frac{1}{2}\right)\right)^2}{2}\right] + \exp\left[-\frac{\left(p_2+\Delta\left(m+\frac{1}{2}\right)\right)^2}{2}\right]\right\}$$

or

$$(13)\qquad Z_0 \simeq \eta\sqrt{N} p_1 \left\{1+2\sum_{k=1}^{\infty}(-1)^k \exp\left[-2\left(\frac{\pi k}{\Delta}\right)^2\right]\cos\frac{2\pi k}{\Delta}p_2\right\}.$$

Series (12) very rapidly converges for $\Delta > \pi$, while (13)—for $\Delta < \pi$. Considering the oddness of $\psi_1^2(\eta)$ and $\psi_2(\eta)$ and the fact that as $p_1 \to 0$, $\psi_2(p_2 \pm p_1) \to \psi_2(p_2)$, $\psi_1^2(p_2 \pm p_1) \to \psi_1^2(p_2)$, for the variance at DSLCF output for $p_1 \ll 1$ we obtain

$$(14)\qquad D\{Z_l\} = D\{Z\} \simeq \psi_2(p_2) - \psi_1^2(p_2) = \sum_{m=-\infty}^{\infty}\{\Delta m - \psi_1(p_2)\}^2 \times \left\{F\left[p_2-\Delta\left(m-\frac{1}{2}\right)\right] - F\left[p_2-\Delta\left(m+\frac{1}{2}\right)\right]\right\}.$$

Figure 2 shows the functions

$$\zeta = \frac{|Z_0|}{\sqrt{D\{Z\}}\sqrt{N}\,\eta p_1} = f\left(\frac{p_2}{\Delta}\right)$$

where $\Delta=\mathrm{const}$, characterizing the worsening signal-to-noise ratio of the main lobe of a weak signal at DSLCF output in comparison with a linear SLCF, depending on the intensity of the second signal, computed by formulas (12), (13), (14).

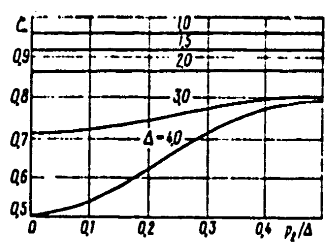



Figure 2

The periodicity of 1 and symmetry of the function $\zeta = f(p_1/\Delta)$ given the variation $p_1/\Delta$ from $-\infty$ to $\infty$, caused by the periodicity and symmetry of quantization error (7), make it possible in Fig. 2 to limit oneself to an interval of the abscissa

Maximum losses in the signal-to-noise ratio in the main lobe of a weak signal, as Fig. 2 shows, is observed for intensities of the second signal $p_1 = m\Delta$, while minimum losses for $p_1 = (m + 1/2)\Delta$ where m is a whole number. The reason for this is that for $p_1 = m\Delta$ the mean value $\xi_1$ of ADC input $\xi_1$ nears the center of the horizontal segment of the characteristic (5), so that the effect of the weak signal on ADC output is minimal. For $p_1 = (m + 1/2)\Delta$ on the contrary, $\xi_1$ occurs at the break point $f(\xi)$, when the presence or absence of a weak signal is maximally felt.

Fig. 2 also indicates that in the resolution of two signals, one of which is weak, the choice of the normalized quantization increment $\Delta \leq 2$ guarantees both a small loss in the signal-to-noise ratio in comparison to a linear SLCF, and an almost total lack of dependence of the mean value and variance of the main lobe of a weak signal on the intensity of the second signal at filter input.

## BIBLIOGRAPHY

1. Bakut, P. A.; Bol'shakov, I. A.; Gerasimov, B. M.; Kuriksha, A. A.; Repin, V. G.; Tartakovskiy, G. P.; Shirokov, V. V. "Voprosy statisticheskoy teorii radiolokatsii" [Topics in the Statistical Theory of Radiolocation], Vol 2, Izd. Sovetskoye radio, 1964.

2. Ipatov, V. P. RADIOTEKHNIKA I ELEKTRONIKA, Vol 22, No 8, 1977, p 1600.

3. Bogner, R., and Konstantinidis, A., editors. "Vvedeniye v tsfrovuyu fil'tratsiyu" [Introduction to Digital Filtering], Izd. Mir, 1976.

4. Levin, B. R. "Teoreticheskiye osnovy statisticheskoy radiotekhniki" [Theoretical Bases of Statistical Radio Engineering], Izd-Sovetskoye radio, 1969.



8506
CSO: 1870

ELECTRONICS AND ELECTRICAL ENGINEERING

UDC 621.391.2

DIGITAL PHASE-LOCKED LOOPS FOR PROCESSING VIDEO SIGNALS

Moscow RADIOTEKHNIKA I ELEKTRONIKA in Russian No 12, Dec 78 pp 2525-2533

/Article by M. I. Zhodzishskiy, signed to press 28 July 77, originally presented at the Second Scientific and Technical Seminar on Phase Synchronization Systems, Gor'kiy, Jun 1975)

/Text/ The probability distribution, expected value, and phase error variance of digital phase-locked loop tracking are analyzed. Phase-locked loop circuits are designed to filter out-of-bound noise and pseudonoisy signals or serve as symbol synchronization systems.

Performance Algorithms

In addition to filtering harmonic signals digital phase-locked loops (DPLL) are used to filter video signals (for symbol synchronization /1, 2/, out-of-bound noise /3, 6/ and pseudonoisy signals). Simple DPLL's have been studied in detail, in which the error signal is generated by using a "zero" input signal and video noise mix, i.e., a short pulse, formed when the input mix passes through zero /1/ (conventionally, the first algorithm). Similar circuits operate well when the signal-to-noise ratio at digital phase detector (DPD) input $s = U_c/\sigma$ (where $U_c$ and $\sigma$ are the signal amplitude and standard deviation of noise, respectively) is significantly greater than unity. However, of no less practical interest today is the case where $s \sim 1$ and especially $s \ll 1$. In these cases DPLL's, using a zero input video signal-noise mix, cannot function normally. To correct this deficiency the operational algorithm of the DPD must be changed.

The second performance algorithm calls for the quantization of the input mix at the moment, $t_k$, the reference oscillation changes sign. The number $z'$, thus generated, in the case of out-of-bound or pseudonoise synchronization, is multiplied by +1 or -1 depending on whether the reference oscillation at moment $t_k$ is positive or negative. During synchronization (without using a separate sync signal) the number $z'$ is stored in a single symbol, at the end of which a special schematic (logic block) determines whether there was a change in binary digits close to $t_k$. Afterwards $z'$ is multiplied by zero, if there was no change; by +1 if the digit +1 changed to -1, and by -1 if the reverse occurred. The number resulting from the multiplication, undergoes further processing through linear smoothing circuits, which are built the same way in known symbol synchronization systems [1] and harmonic signal DPLL's [4]. An example of this circuit is shown in Fig. 1 (for a first order astatic state and binary quantization of the input mix). In this circuit the limiter (Lim) rigidly limits the input mix; the correctible counter $CC_1$ acts as a digital integrator (according to the sign of the number in the $CC_1$ before dumping, an evaluation of the transmitted symbol is made: +1 or -1); $CC_2$ (with numerical coefficient $n_r$) controls the transmission factor of the DPLL circuit, and the divide counter (with numerical coefficient $n_x$) reduces the phase jump of the input signal to $2\pi/n_x$.

If the binary quantization of the input mix is allowed, then the described algorithms make it possible to construct simple DPLL's for video signals. When binary quantization is undesirable (due to energy loss) in the information channel, but allowable in the synchronization circuit, one can apply the circuit with secondary (binary) quantization [3, 6] (conventionally, the third algorithm). In this circuit during a single symbol (pulse) of the input video signal a sufficiently large number of multilevel readings are produced, which undergo further processing in the information channel. In the synchronization circuit from these readings are selected only those at the moment the video input signals hypothetically change sign; they are multiplied by $\pm 1$ (depending on the direction of change in sign) and summed in several pulses. The result of the summation undergoes binary quantization, making it possible to apply the same simple linear smoothing circuits, which are also part of the algorithms described above.

All three algorithms examined here are entirely realized as digital microcircuits. The known DPLL's for video signals are built using digital and analog elements [2, 7]. In these systems, instead of quantization of the input mix at the moment the output pulse appears, quantization of the integration result occurs for the gate length ($\tau_g$), whereas the time shift of the gate is determined by the phase of the output signal (conventionally, the fourth algorithm).

## 2. Discrimination and Fluctuation Characteristics. The Quasilinear Mode

In analyzing DPLL's for a video signal we will use the same quasi-continuous method that is also used in analyzing harmonic signal DPLL's [4]. In general (for a harmonic signal especially), the computation of the fluctuation characteristic of the equivalent discriminator $N_д$ appears relatively cumbersome. However, this article examines the case of uncorrelated readings $z_д[r]$ at DAC output, for which, from formula (4) in [4], we obtain the following simple formula:

(1) $$N_д = 2D_z/F,$$

where $D_z$ is the variance of $z_д[r]$; $F$ —quantization frequency.

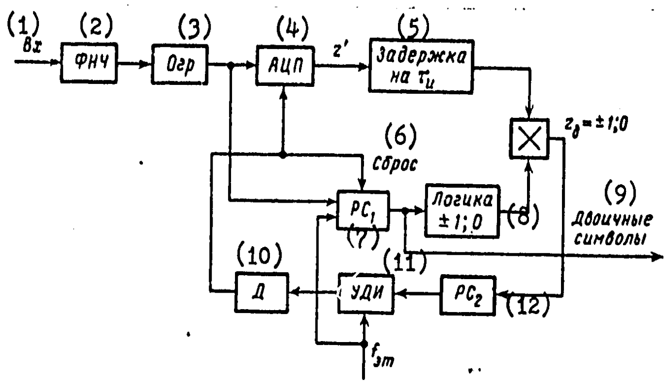



Figure 1

Key:

1. Input
2. Low Pass Filter
3. Limiter
4. Analog-Digital Converter
5. Delay
6. Dump
7. Correctible Counter 1
8. Logic
9. Binary symbols
10. Divide Counter
11. Adder/Subtracter
12. Correctible Counter 2

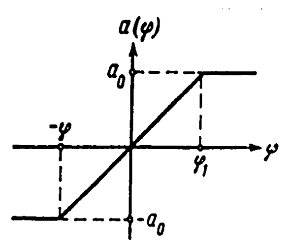



Figure 2

Here we are interested in the fixed mode, in which the phase error of DPLL tracking $\varphi = \varphi_c - \varphi_{вых}$ (the difference between the phase of the input signal less noise and the output phase) is less than the periodicity interval of the discrimination characteristic (DC) and this periodicity may be ignored. Moreover, as will be seen further, the form of the DC $a(\varphi)$ is well approximated by the varying linear function in Fig. 2. If $|\varphi| < \varphi_1$, then a quasilinear operation mode occurs. In this mode the phase error $\varphi(t)$ is normally distributed with variance

(2) $$\sigma_\varphi^2 = N_э \Delta f_э,$$

where $N_э = N_д / k_д^2$ is the equivalent fluctuation characteristic; $k_д = [da(\varphi)/d\varphi]_{\varphi=0}$ —transmission factor of the discriminator; $\Delta f_э$ —the equivalent bandwidth of the DPLL. For second order astatic state DPLL's the transfer function of the linear smoothing circuits can be represented as

(3) $$K(p) = (k_п/p)(1 + 1/pT_и),$$

when

(4) $$\Delta f_э = (k/4)(1 + 1/kT_и),$$

where $k = k_д k_п$.

For first order astatic state in (3) and (4) it must be assumed that $T_и \to \infty$. For a standard linear smoothing circuit configuration (as, for example, in Fig. 1) $k_п = 2\pi F / n_у n_д$.

In finding $a(\varphi)$ and $N_д$ for symbol synchronization systems, which appear to be simultaneously demodulation (detector) systems for binary data symbols, we will ignore the affect of errors in detecting symbols in DPLL operation, which is allowable for small probabilities of error in detection. We will also ignore the difference in the +1 or -1 values of pseudonoisy signals. Our analysis will concern itself with the more prevalent case of binary quantization. The formulas presented below relate directly to the synchronization of an out-of-bound signal. For the synchronization of pseudonoisy signals and for symbol synchronization half of the error signals $z_д[r]$ are equal to zero on the average; therefore, $a(\varphi)$, $k_д$, $N_д$, $\Delta f_э$ are halved; $N_э$ is doubled, and $\sigma_\varphi^2$ remains unchanged.

We will compute the characteristics for the first algorithm. At the transmitting end of the radio circuit the video signal can be viewed as split, i.e., a signal with infinitely steep edges. However, because of the limited bandwidth of the receiver (from the antenna to the generator of the zero input mix) the edges collapse. We will take the often used varying linear approximation of the signal shape at receiver output ([1], p 95; [3]) with leading edge pulse time $\tau_{фр} = 1/2\Delta F_ф$ ([8], p. 369), where $\Delta F_ф$ is the equivalent receiver bandwidth (i.e., the LPF bandwidth with rectangular frequency characteristic from 0 to $\Delta F_ф$ Hz, equivalent to a receiver). We will consider the fluctuations of the pulse edges at receiver output to be independent, and that the condition $\tau_и \gg 1/2\Delta F_\Phi$ is met, where $\tau_и$ is pulse (symbol) length for symbol synchronization and pseudonoise or the half-period of out-of-bound noise. The noise variance at receiver output $\sigma^2 = N_0 \Delta F_\Phi$, where $N_0$ is the spectral density of white noise at input (transmission factor of the receiver in the transmission band is conventionally accepted to be unity). For the first algorithm at receiver output the condition $s \gg 1$ obtains, for which the probability distribution of zero fluctuations is practically normal ([1], p. 28; [9], p. 260), whereas the time fluctuation variance $\sigma^2_{\tau вх} = \sigma^2/l^2$, where $l = 2U_0/\tau_\Phi$, is the slope of the pulse edge. After recomputing these time fluctuations into phase fluctuations (according to the formula $\varphi_{вх} = 2\pi\tau_{вх}/\tau_и$), we obtain

$$\sigma^2_{\varphi вх} = \frac{\pi^2 N_0}{4\tau_и^2 U_0^2 \Delta F_\Phi}. \tag{5}$$

The error signal $z_д[r]$ takes the values +1 and -1 with the following probabilities:

$$P(+1) = \Phi(\varphi/\sigma_{\varphi вх}), \quad P(-1) = 1 - P(+1).$$

From here it is easy to obtain the following expression for the discrimination characteristic:

$$a(\varphi) = P(+1) - P(-1) = 2\Phi(\varphi/\sigma_{\varphi вх}) - 1.$$

This characteristic is well approximated by the varying linear function (Fig. 2) with a slope (for the sloped portion) equal to

$$k_д = \frac{2U_0 \tau_и \sqrt{2\Delta F_\Phi}}{\pi \sqrt{\pi} \sqrt{N_0}}, \tag{6}$$

and with horizontal portion $a_0 = 1$.

In the most feasible case for the first algorithm $|\varphi| \ll \varphi_1$ we have $D_1 \simeq 1$, from which $N_д = 2\tau_и$ (since $F = 1/\tau_и$). Using the formula derived above for this case it is not difficult to obtain (for a first order astatic state)

$$\Delta f_э = \frac{U_0}{n_у n_д} \sqrt{\frac{2\Delta F_\Phi}{\pi N_0}}, \tag{7}$$

$$\sigma_\varphi^2 = \frac{\pi^2}{2U_0 \tau_и n_у n_д} \sqrt{\frac{\pi N_0}{2\Delta F_\Phi}}. \tag{8}$$

Using (5) one can transform (8) into the familiar form presented in [1, 9]:

$$\sigma_\varphi^2 = \frac{\pi\sqrt{\pi}}{\sqrt{2}\,n_y n_\text{д}}\sigma_{\varphi\text{э}1}. \qquad (9)$$

We now obtain the characteristic for the second algorithm. As in the case of the first algorithm, we assume that the video signal mix arrives at ADC input with a leading pulse edge time $\tau_{\Phi\text{р}}=1/2\Delta F_\Phi$ and normal noise with variance $\sigma^2=N_0\Delta F_\Phi$. The probabilities of the +1 and -1 signals at ADC output in this case are

$$P(+1)=\Phi(u_{\text{сн}}/\sigma);\quad P(-1)=1-P(+1),$$

where $u_{\text{сн}}$ is the signal value at the moment of quantization, from which

$$a(\varphi)=2\Phi(u_{\text{сн}}/\sigma)-1.$$

In the most interesting case for this algorithm, $s\ll 1$, we have $D_1\simeq 1$ and $N_\text{д}\simeq 2\tau_\text{и}$. Here the DC takes on the form shown in Fig. 2, while $a_0=\sqrt{2}s/\sqrt{\pi}$, and for $k_\text{д}$, $\Delta f_\text{э}$ and $\sigma_\varphi^2$ formulas (6)-(8) are still valid. We emphasize, however, that the first algorithm works for $s\gg 1$, while the second algorithm (as well as the third and fourth) work for random s.

We now consider the third algorithm. It is convenient here to consider the output of the discriminator as the output of a binary quantizer. To find $a(\varphi)$ and $N_\text{д}$ one must first determine the ratio ($w$) of the expected value to the standard deviation of noise at quantizer input. Ignoring quantization error of the first quantizer, we find

$$w=\sqrt{m}\,u_{\text{сн}}/\sigma,$$

where m is the number of averageable readings (between the first and second quantizer); $u_{\text{сн}}$ and $\sigma$ —signal value (at the moment of quantization) and the standard deviation of noise at first quantizer input. Since processing the binarily quantized readings here does not differ from a similar processing in the preceding algorithms, the formulas derived above still apply, so long as s is replaced by $s\sqrt{m}$. We will apply these formulas to calculate DPLL's of the second order astatic state examined in [3]. An equivalent transfer function of the linear smoothing circuits in this system equals

$$K(p)=\frac{4\pi F\Delta_1}{p}\left(1+\frac{\Delta_2 F}{\Delta_1 p}\right), \qquad (10)$$

where $F=m\tau_\text{и}$; $\Delta_1$ and $\Delta_2$ are coefficients in the proportional and integrating loops of the system (see Fig. 1 in [3]). By comparing (10) and

(3) we find $k_в = 4\pi F\Delta_1$, $T_в = \Delta_1/\Delta_2 F$. Substituting these expressions in (4), we find

$$(11) \qquad \Delta f_э = \frac{\Delta_1 s}{\sqrt{\pi m/2}\,\tau_{фр}} + \frac{\Delta_2}{4\Delta_1 m \tau_в}.$$

As applied to the system under examination formulas (6) and (8) reduce to the following:

$$(12) \qquad k_д = \frac{\sqrt{2m}\,\tau_в s}{\pi^{3/2}\tau_{фр}},$$

$$(13) \qquad \sigma_\varphi^2 = \frac{\pi^{5/2}\tau_{фр}\Delta_1\sqrt{2}}{s\sqrt{m}\,\tau_в} + \frac{\pi^2\tau_{фр}^2\Delta_2}{4ms^2\tau_в^2}$$

Formulas (11)—(13) for $\Delta f_э$, $k_д$, $\sigma_\varphi^2$ coincide with formulas (18), (13), (20) in [3] for $W_L$, $A_{eq}$, $\sigma_L^2$, if one assumes the following correspondence in notation between this work and [3]: $m \leftrightarrow 2M$; $U_c \leftrightarrow A$; $\tau_{фр} \leftrightarrow \Delta T_0$; $n_д \leftrightarrow N$; $2\tau_в \leftrightarrow T_0$; $ms^2 \leftrightarrow \rho$. In making the comparison one should keep in mind that we are using here a one-sided bandwidth $\Delta f_э$ and one-sided spectral densities ($N_0$, $N_д$), whereas in [3] $W_L$ is a two-sided bandwidth, $N_0$—a one-sided spectral density, and $S_n(0)$—two-sided; therefore, $N_д = 2S_n(0)$; $W_L = 2\Delta f_э$. The phase in this study is related to pulse length ($\varphi = 2\pi\tau/\tau_в$), whereas in [3]—to the period of output fluctuation ($\Phi = 2\pi\tau/T_0$); therefore, $\varphi = 2\Phi$, $A_{eq} = 2k_д$, $\sigma_\varphi^2 = 4\sigma_L^2$. The quantity $n_д$ for us is equal to the ratio of reference pulses, entering the adder/subtracter, to the frequency of the first quantization ($1/\tau_в$), which is twice as great as the frequency of the output signal in [3] (since two readings are generated for one output signal period in [3]).

The fact that the formulas here agree with those in [3] is no accident: [3] also uses a quasicontinuous method for the simplest case of independent error signals $z_д[r]$ and quasilinear operational mode. The authors of [3] note the "striking coincidence" of their data derived in this way with the experimental results having little error (i.e., quasilinear mode). However, both conditions (independence and quasilinearity) are not required to apply the quasicontinuous method [4].

We turn to the fourth algorithm. To simplify matters we assume that the gate length $\tau_0$ is much greater than the length of the leading pulse edge of a signal at integrator input and for this reason, it is neglected. Moreover, it is easy to see that the variance and expected value of the process at ADC input are

$$\sigma_x^2 = \tau_0 N_0/2; \quad \bar{u}_{x2} = U_c \tau_в \varphi/\pi \quad (\text{for } |\varphi| < \varphi_1),$$

hence

$$P(+1)=\Phi[U_c\tau_n\varphi\sqrt{2}/(\pi\sqrt{\tau_0 N_0})];\quad P(-1)=1-P(+1). \tag{14}$$

Comparison of (14) with the corresponding expressions for the algorithms, previously examined, confirm that all the formulas derived above are still valid, if $\tau_{\phi p}=1/2\Delta F_\phi$ is changed to $\tau_0$. The shape of the DC in this case also corresponds to that in Fig. 2.

3. Nonlinear Mode

In analyzing a nonlinear mode we limit ourselves to an examination of DPLL's of a first order astatic state. With the aid of the structural schematic of the quasicontinuous analog (Fig. 1 in [5]), valid for synchronization of signals of any form, and of expression (3) (for $T_n\to\infty$), it is not difficult to formulate the following differential equation:

$$\dot\varphi=\dot\varphi_c-k_n[a(\varphi)+\sqrt{N_n}\zeta(t)]. \tag{15}$$

Here $\dot\varphi_c$ represents the initial detuning of the input signal frequency; $\zeta(t)$ —normalized white noise, at which

$$\overline{\zeta(t)\zeta(t-\tau)}=0{,}5\delta(t). \tag{16}$$

The differential equation (15) corresponds to the following Fokker-Plank equation for phase error probability density $w(\varphi)$:

$$\frac{\partial w}{\partial t}=-\frac{\partial}{\partial\varphi}\{A(\varphi)w\}+0{,}5\frac{\partial^2}{\partial\varphi^2}\{Bw\}, \tag{17}$$

where

$$A(\varphi)=\dot\varphi_c-k_n a(\varphi);\quad B=0{,}5N_n k_n^2. \tag{18}$$

In this case the probability of large errors $|\varphi|$ can be ignored; therefore, the probability flux in a steady-state mode is nonexistent and the steady-state distribution appears as

$$w_{st}(\varphi)=(c/B)\exp\left\{2\int[A(\varphi)/B]d\varphi\right\}. \tag{19}$$

Expressions (15)—(19) are valid for any form of signals. Substituting expressions $A(\varphi)$ and B in (19) for video signals and integrating, we obtain

$$w_1(\varphi)=c_1\exp[4(\dot\varphi_c+k_n a_0)\varphi/N_n k_n^2]\ \text{for}\ \varphi<-\varphi_1, \tag{20}$$

$$w_2(\varphi)=c_2\exp[-2a_0(\varphi-\dot\varphi_c\varphi_1/k_n a_0)^2/N_n k_n\varphi_1)\ \text{for}\ -\varphi_1<\varphi<\varphi_1, \tag{21}$$

$$w_3(\varphi)=c_3\exp[4(\dot\varphi_c-k_n a_0)\varphi/N_n k_n^2]\ \text{for}\ \varphi>\varphi_1. \tag{22}$$

Coefficients $c_1, c_2, c_3$ are based on conditions

$$w_1(-\varphi_1)=w_2(-\varphi_1);\ w_2(\varphi_1)=w_3(\varphi_1);$$

$$\int_{-\infty}^{+\infty} w_{\text{ст}}(\varphi)\,d\varphi=1.$$

Performing the corresponding transformation and introducing the notation

$$r=\sqrt{N_{\text{д}}k_{\text{п}}/4a_0},\ y=\sqrt{4a_0\varphi_1/N_{\text{д}}k_{\text{п}}},$$
$$z=\dot\varphi_c/k_{\text{п}}a_0,$$

we find

$$1/c_2^0=1/yr^2c_2=[1/y(1+z)]\exp[-y^2(1+z)^2/2]+$$
$$+[1/y(1-z)]\exp[-y^2(1-z^2)/2]+\sqrt{2\pi}\{\Phi[y(1-z)]+$$
$$+\Phi[y(1+z)]-1\},\quad c_1^0=c_3^0=c_1yr^2=c_2\exp[0{,}5y^2(1-z^2)].$$

Obviously, from expressions (20)—(22), the probability distribution $w_{\text{ст}}(\varphi)$ consists of segments of exponential and normal distributions. Moreover, quantity r appears to be some kind of characteristic of the fluctuating properties of the system, while $k_{\text{п}}a_0$ —a synchronization bandwidth. The value y characterizes the relative length of the sloped section of the DC, whereas z represents the relative value of the initial detuning. For $y>(3-5)$ and small z the DPLL circuit examined here behaves almost like a linear system, while for $y<0{,}5$—like a continuous system (i.e., a system with continuous DC). In the first case

$$w_1(\varphi)\simeq w_3(\varphi)\simeq 0;\ w_{\text{ст}}(\varphi)\simeq w_2(\varphi);$$
$$c_2=\sqrt{2a_0/\pi N_{\text{д}}k_{\text{п}}\varphi_1}.$$

In the second one may ignore the middle section of the probability distribution ($w_2(\varphi)$) and consider only two exponentional functions $w_1(\varphi)$ and $w_3(\varphi)$ , in which

$$c_1=c_3=2[(k_{\text{п}}a_0)^2-(\dot\varphi_c)^2]/k_{\text{п}}^2a_0N_{\text{д}}.$$

With the aid of (20)—(22) one can find the following expressions for the expected value and standard deviation of the phase error:

$$\overline{\varphi}=zr^2f_1(y,z),\ \sigma_\varphi^2=r^4f_2(y,z), \tag{23}$$

where (Fig. 3 and 4)

$$f_1(y,z)=(c_1^0y/z)\Big\{\langle-\exp[-y^2(1+z)]\rangle\times \tag{24}$$
$$\times\left\langle\frac{1}{1+z}+\frac{1}{y^2(1+z)^2}\right\rangle+\langle\exp[-y^2(1-z)]\rangle\times$$
$$\times\left\langle\frac{1}{1-z}+\frac{1}{y^2(1-z)^2}\right\rangle\Big\}+(c_2^0y/z)\{\exp[-y^2(1+z)^2/2]-$$
$$-\exp[-y^2(1-z)^2/2]+\sqrt{2\pi}\,yz\langle\Phi[y(1-z)]+\Phi[y(1+z)]-1\rangle\};$$

$$(25)\quad \begin{aligned} f_2(y,z)=c_1^0y^2\{&\langle\exp[-y^2(1+z)]\rangle\langle y/(1+z)+\\ &+2/y(1+z)^2+2/y^3(1+z)^3\rangle+\langle\exp[-y^2(1-z)]\rangle\times\\ &\times\langle y/(1-z)+2/y(1-z)^2+2/y^3(1-z)^3\rangle\}+\\ &+c_2^0y^2\{-y(1+z)\exp[-y^2(1-z)^2/2]-y(1-z)\times\\ &\times\exp[-y^2(1+z)^2/2]+\sqrt{2\pi}(1+y^2z^2)\times\\ &\times\langle\Phi[y(1-z)]+\Phi[y(1+z)]-1\rangle\}-z^2f_1^2(y,z). \end{aligned}$$

Analysis of functions (24) and (25) shows that $\bar{f}_1(y, z\to 0)=f_2(y, z=0)$.

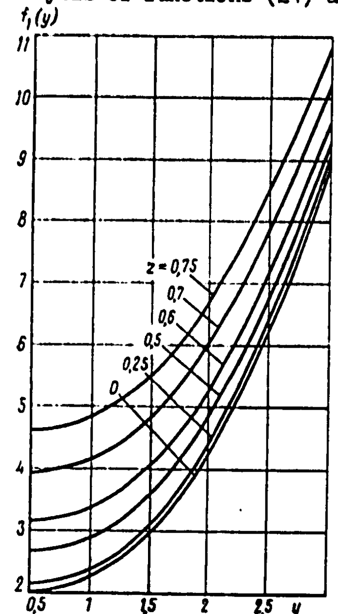



Figure 3

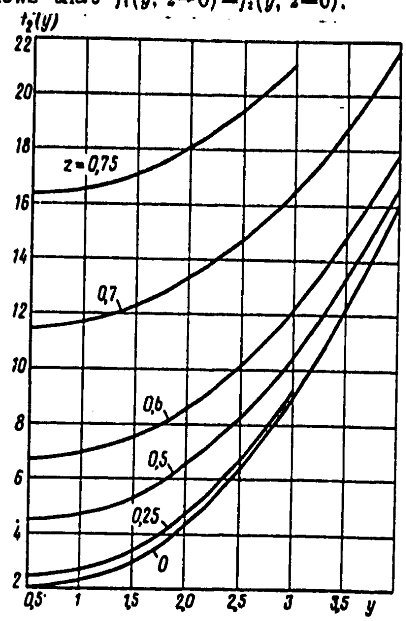



Figure 4

The following asymptotic approximation is valid for a quasilinear mode:

$$f_1(y,z)\simeq f_2(y,z)\simeq y^2.$$

In discontinuous mode

$$f_1(y,z)\simeq\frac{2}{1-z^2},\quad f_2(y,z)\simeq\frac{2(1+z^2)}{(1-z^2)^2}.$$

In particular, for the DPLL's examined in [6], using these formulas it is not difficult to derive (for a discontinuous mode given z = 0)

$$(\sigma_\varphi/\Delta_\varphi) = \sqrt{\pi}/2\sqrt{\rho}, \quad (26)$$

where $\Delta_\varphi = 2\pi/n_k$; $\rho = ms^2$. A comparison of the results computed from formula (26) with the results obtained by discrete Markov chains [6] shows that error in calculating the variance by the quasicontinuous method does not exceed the value of the internal phase fluctuations $(\Delta_\varphi^2/4)$ given any s*. In practical circuits this value (i.e., variance of phase fluctuations at system output in the absence of input fluctuations) becomes a fortiori small. The results derived from formula (26) (solid curve) and from (14) in [6] (crosses) are presented in Fig. 5, which also shows the straight dot-dash line $\sigma_\varphi/\Delta_\varphi = 0{,}5$, corresponding to internal phase noise. We note that $\sigma_{T\varepsilon}/\Delta$ is practically independent of N for the usually encountered case $N \geq 32$.

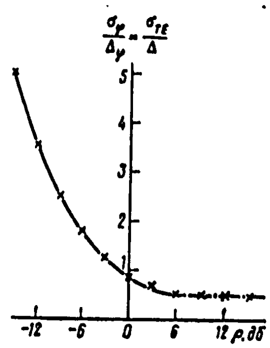



Figure 5

With the help of graphs in Fig. 3 and 4 it is not difficult to determine $\varphi$ and $\sigma_\varphi^2$ for mean y values $(0{,}5 \leq y \leq 3)$.

---

*For comparison it should be kept in mind that in [6], like [3], $\Delta$ and $\sigma_{T\varepsilon}$ stand for a loop sample and input signal fluctuations in fractions of its period $(\Delta_\varphi = 4\pi\Delta)$, while in Fig. 5 and 12—phase fluctuations in degrees $\sigma_\Phi = 2\pi\sigma_{T\varepsilon} = \sigma_\varphi/2$, from which, using (26), we have $\sigma_\Phi = \pi\sqrt{\pi}\Delta/\sqrt{\rho}$.

Analysis of the derived expressions shows that in the last three algorithms a change in bandwidth $\Delta F_\phi$ (gate $\tau_\phi$) leads to a change in $a_0$, and consequently, a change in the synchronization bandwidth $k_n a_0$. To keep it from changing with a k-factor increase in $\Delta F_\phi$(decrease in $\tau_\phi$) $k_n$ must be increased $\sqrt{k}$ -fold. In this case increaseing $\Delta F_\phi$(decreasing $\tau_\phi$) results in: for a quasilinear mode—a reduction in $\phi$ given $\sigma_\phi^2$ does not change; for a discontinuous mode—an increase in both errors. Consequently, the optimum $\Delta F_\phi$ (or $\tau_\phi$) value corresponds to the mean y value between the quasilinear and discontinuous mode. These properties essentially separate video signal DPLL circuits from harmonic DPLL circuits.

## BIBLIOGRAPHY

1. Ginzburg, V. V.; Kayatskas, A. A. "Teoriya sinkhronizatsii demodulyatorov" [The Theory of Demodulator Synchronization], Izd. Sbyaz', 1974.

2. Hurd, W. J., Anderson, T. O. IEEE TRANS. COMMUN. TECHNOLOGY, Com-18, No 2, 1970, p 141.

3. Holmes, J. K.; Tegnellia, C. R. IEEE TRANS. COMMUN., Com-22, No 1, 1974, p 62

4. Zhodzishskiy, M. I. RADIOTEKHNIKA I ELEKTRONIKA, Vol 18, No 5, 1973, p. 979.

5. Zhodzishskiy, M. I. RADIOTEKHNIKA I ELEKTRONIKA, Vol 18, No 4, 1973, p 796.

6. Holmes, J. K. IEEE TRANS. COMMUN., Com-20, No 2, 1972, p 119.

7. Cessna, J. R.; Levy, D. M. IEEE TRANS. COMMUN., Com-20, No 2, 1974, p 94.

8. Tinugin, V. N.; Veytsel', V. A. "Radioupravleniye" [Radio Wave Control], Izd. Sovetskoye radio, 1962.

9. Shlyapoberskiy, V. I. "Osnovy tekhniki peredachi diskretnykh soobshcheniy" [Basic Technology of Digital Information Transmission], Izd. Svyaz', 1973.



8506
CSO: 1870

## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

### VIKTOR AMAZASPOVICH AMBARTSUMYAN

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 2, 1979 p 123

[Article commemorating V. A. Ambartsumyan's 70th birthday]

[Text] Academician Viktor Amazaspovich Ambartsumyan, Hero of Socialist Labor and President of ArmSSR Academy of Sciences, by ukase of the Presidium of the USSR Supreme Soviet dated 15 September 1978, was awarded the Order of Lenin and his second gold Hammer and Sickle medal for outstanding services in the development of Soviet science and in connection with his 70th birthday.

To mark the labor exploits of V. A. Ambartsumyan, Hero of Socialist Labor, a bronze bust will be erected in his homeland.

V. A. Ambartsumyan is one of the founders of theoretical astrophysics in the USSR. At the same time as the Dutch astronomer Zanstra he created a physical theory of gaseous nebulas, being one of the first to draw attention to the importance of nonstationary phenomena in space in understanding the processes of stellar evolution; and developed methods for evaluating the loss of mass by nonstationary stars and novas. V. A. Ambartsumyan first showed the meaning of stellar associations in solving the question of the origin of stars, thereby solving one of the problems of modern stellar cosmogony. He is credited with the introduction in science of the concept of galactic nuclear activity.

The value of the works of V. A. Ambartsumyan on the theory of transmission of emission, especially the principle he formulated of invariance, has gone far beyond the framework of astrophysics. These works formed the basis for research into the phenomena of transmission in the most diverse fields of science.

V. A. Ambartsumyan has given much attention to the training of scientific personnel. Among his numerous pupils are members of USSR Academy of Sciences and academics of sciences of Union republics.

V. A. Ambartsumyan has worked for over 30 years as President of ArmSSR Academy of Sciences, which became one of the leading centers of Soviet science. He is head of the Byurakan Observatory which he created.

The activity of V. A. Ambartsumyan is widely known in international scientific organizations. For many years he was vice-president and president of the International Astronomical Union and president of the International Council of Scientific Unions.

The scientific services of V. A. Ambartsumyan have received high evaluation throughout the world. He is a laureate of USSR State Awards, has been honored with the gold medal and Award imeni M. V. Lomonosov of USSR Academy of Sciences, gold medals of the British Royal and Pacific Ocean Astronomical Societies, and has been elected a foreign and honorary member of many academies of sciences and scientific societies.

V. A. Ambartsumyan is a member of the CPArm Central Committee and is a deputy of the USSR Supreme Soviet.



8617
CSO: 1870

## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

### VALENTIN PETROVICH GLUSHKO

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 2, 1979 p 124

[Article commemorating V. P. Glushko's 70th birthday]

[Text] Academician Valentin Petrovich Glushko, Hero of Socialist Labor, laureate of the Lenin and State Prizes, has reached his 70th birthday.

The Presidium of USSR Academy of Sciences sent V. P. Glushko a letter of greetings in which his scientific and science-organizational activity was described.

From the first small experimental jet engines designed by V. P. Glushko in the years 1930-1931, says the greeting, to the family of powerful rocket motors of today--this is the path of the founder of Soviet rocket motor construction.

In 1957, motors designed by V. P. Glushko launched the first artificial Earth satellite in human history into orbit. Since then his engines have bee placed in all missile systems; consequently our country has attained remarkable successes in the study and mastery of outer space.

V. P. Glushko is author of 245 scientific and popular science treatises (published since 1924).

In the greeting is noted V. P. Glushko's ability to unite large scientific research collectives and to direct them to solve complex scientific and technical problems. V. P. Glushko has been the continuous leader of the scientific research and test design organization (GDL-OKB) proposed by him which, in 1979, was 50 years old.

V. P. Glushko has given much attention to scientific organization activities of USSR Academy of Sciences. Everyone knows of the tremendous contribution of V. P. Glushko to the creation of the three fundamental reference works of USSR Academy of Sciences on the thermochemical, thermodynamic and thermophysical properties of substances, including products of fuel combustion. These reference books, which have received world-wide recognition, provide the initial data to all forms of scientific and engineering and design studies.

V. P. Glushko was awarded by gold medal imeni K. E. Tsiolkovskiy by USSR Academy of Sciences.

V. P. Glushko's scientific and organizational work is combined with great socio-political activity. He is a member of CPSU Central Comittee and is a deputy of the USSR Supreme Soviet.

V. P. Glushko, constructor general, has been awarded five Orders of Lenin and other orders and medals.

In Odessa where V. P. Glushko was born his bronze bust was erected and a memorial plaque was set on the house in which he lived. Odessa elected V. P. Glushko as its honored citizen.

The Presidium of USSR Academy of Sciences wished V. P. Glushko good health, inexhaustable energy, and new creative accomplishments.



8617
CSO: 1870

## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

### SERGEY L'VOVICH SOBOLEV

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 2, 1979 p 125

[Article commemorating S. L. Sobolev's 70th birthday]

[Text] By ukase of the USSR Supreme Soviet dated 5 October 1978, for services in development of Soviet science, training of scientific personnel, and on the occasion of his 70th birthday, Sergey L'vovich Sobolev was awarded the Order of the October Revolution.

The fundamental results obtained by Academician S. L. Sobolev, Hero of Socialist Labor, had an exceptional effect on the development of mathematics. At the very start of his creative activity, he ran a series of outstanding experiments in theoretical and applied mathematical physics. The works of S. L. Sobolev in the dynamic theory of elasticity, diffraction of flat waves and the solution to the Cauchy problem for hyperbolic equations made his name a household word among mathematicians.

Back in the 1930s, far anticipating his time, S. L. Sobolev laid the foundations for a new approach to the problem of mathematical physics, introducing the concept of a generalized solution, generalized derivative, and generalized function. The theory of generalized functions is today a necessary instrument for all research connected with the solution of differential equations.

In the field of boundary problems for elliptical equations, S. L. Sobolev created a new branch of functional analysis--the theory of embedding of functional spaces. Research in this direction has now been intensively developed throughout the world and has found various applications.

S. L. Sobolev's achievements in solving equations of small oscillations of a rotating liquid led to profound results in the spectral theory of operators; his work on the theory of cubature formulas are recognized as a model of brilliant solution of a mathematical problem.

While deputy director of the Institute of Atomic Energy, S. L. Sobolev put together a large collective of mathematicians who, under his leadership, solved a series of problems important for our country.

S. L. Sobolev is one of the organizers of the Siberian Section USSR Academy of Sciences, a founder and continuous director of the Institute of Mathematics of the Siberian Section USSR Academy of Sciences, member of the bureau of the Division of Mathematics, member of the Committee on the USSR Lenin and State Prizes in Science and Technology at the USSR Council of Ministers.

S. L. Sobolev's services are great in the training of scientific personnel. The many monographs and textbooks he set up have become the reference books of mathematicians around the world.

S. L. Sobolev was elected a foreign member of many leading foreign academies.

In the note of greetings sent to the celebrant, the Presidium of USSR Academy of Sciences wished Sergey L'vovich health, long life, and new creative successes to the benefit of Soviet science.



8617
CSO: 1870

## SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

### IL'YA MIKHAYLOVICH FRANK

Moscow VESTNIK AKADEMII NAUK SSSR in Russian No 2, 1979 p 126

[Article commemorating I. M. Frank's 70th birthday]

[Text] For services in developing Soviet science, training scientific personnel and on the occasion of his 70th birthday, Academician Il'ya Mikhaylovich Frank was awarded the Order of the October Revolution by ukase of the Presidium of the USSR Supreme soviet dated 20 October 1978.

I. M. Frank arrived in science in a period of formation and violent development of Soviet physics; his contribution to its remarkable achievements is ponderous and many-faceted.

His works on explaining the nature of the "enigmatic" Vavilov-Cherenkov luminescence and further development of optics of charged particles, enriched physics theory with new ideas, received world acclaim, and strengthened the authority of Soviet science.

During the war and the first years thereafter, when the Motherland was occupied with those problems, he took active part in solving the nuclear problem, successfully carrying out a large problem of scientific research connected with the establishment of Soviet nuclear reactors and the study of processes of interaction of neutrons with matter. During this period he developed theoretically new methods of study which were later to receive wide dissemination.

Almost since the very start of his scientific activity, having shown interest towards the then only just nascent nuclear physics, I. M. Frank did much to develop this field of knowledge and became one of the founders of domestic science on the atomic nucleus.

Research trends such as the utilization of nuclear photoemulsions to study nuclear processes, the application of pulsed reactors in neutron spectroscopy, the production and utilization of ultracold neutrons sprung up and evolved under his leadership. With his direct participation important results were obtained in the study of atomci nuclei using neutrons, in studying the process of nuclear fission, nuclear reactions in light nuclei, and other fields of nuclear physics.

The successful solution of all these problems would be impossible without the great, intense scientific and organizational work being done by I. M. Frank in the posts of bureau member of the Division of Nuclear Physics USSR Academy of Sciences, directors of the neutron physics laboratory of the Combined Institute of Nuclear Research, chief of the laboratory of the atomic nucleus of the Physics Institute imeni P. N. Lebedev, and then the Institute of Nuclear Research USSR Academy of Sciences. The scientist has paid much attention to the training of experts in nuclear physics.

Recognition of the great scientific services of I. M. Frank took the form of an award of the USSR State Prize, high governmental awards, and the Nobel Prize in Physics.

The Presidium of USSR Academy of Sciences in its greetings cordially congratulated the celebrant and wished him robust health, happiness, new discoveries and achievem ıts, and fruitful scientific activity to the benefit of our Motherland.



8617
CSO: 1870

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

UDC 001.5

## BASIC TRENDS OF SCIENTIFIC RESEARCH OF THE ARMSSR ACADEMY OF SCIENCES

Moscow VESTNIK AN SSSR in Russian No 2, 1979 pp 3-10

[Report by V. A. Ambartsumyan, president, ArmSSR Academy of Sciences]

[Text] At the end of 1978 the ArmSSR Academy of Sciences marked its 35th anniversary. It now consists of 30 scientific institutions, including 28 institutes. Over 7000 persons work in the academy, among these about 200 doctors of sciences.

The Presidium of the USSR Academy of Sciences discussed the basic trends and future of development of scientific research of the ArmSSR Academy of Sciences. A report was read by V. A. Ambartsumyan, President of the ArmSSR Academy of Sciences.

Report of V. A. Ambartsumyan

The basic mission facing the ArmSSR is defined in resolutions of the 25th CPSU Congress, 26th ArmSSR CP Congress, in addition to decrees of the CPSU Central Committee and USSR Council of Ministers on issues of further development of industry and agriculture. In particular, in the republic it is envisaged that there will be development of radio engineering industry, instrument construction, machine tool construction, etc. These decisions will greatly determine the trends of work of scientific organizations. Therefore the ArmSSR Academy of Sciences has reconsidered its themes of scientific research. More than 200 topics of on-going work are linked with specific problems of the national economy.

The speaker noted that since its formation, the ArmSSR Academy of Sciences has striven to have its own personality and in no way to be a miniaturized version of the Academy of Sciences of the land. This principle has justified itself in practice: more or less significant successes of ArmSSR Academy of Sciences have been achieved wherever this has been done. Furthermore, the speaker reported on some specific achievements and basic trends of scientific research of the ArmSSR Academy of Sciences.

At the Institute of Mathematics, ArmSSR Academy of Sciences, important results have been obtained in theory of functions, especially theory of complex variable functions. These results led to great success in the theory of approximations in complex fields.

Interesting results have recently been attained in a modern section of mathematics such as integral geometry, closely linked with the geometric theory of probabilities.

V. A. Ambartsumyan mentioned that successes in integral geometry have been attained due to the utilization of combinatory methods on one hand, and certain methods of mathematical physics, intensively developed by Armenian theoretical astrophysicists in solving problems of the theory of transfer of emission on the other hand.

The academy-based Yerevan Institute of Mathematical Machines, based on the initiative of Armenian mathematicians, is now engaged in work whose volume is only slightly less than that of the academy as a whole. In addition, industrial enterprises have been formed in the republic for the construction of computers. The initiative of the academy has been very valuable here too.

The speaker noted shortcomings in the work of the academy's Computer Center which has hardly tackled questions of computer mathematics, whereas computer hardware will soon hold a visible place in the industry of the republic.

Great achievements have marked the activity of the Byurakan Astrophysical Observatory. On the whole, the observatory is involved with problems of non-stationary stars and extragalactic astronomy where the attention of scientists has also been focused on non-stationary objects. Hundreds of new flaring stars in stellar clusters and associations. The Byurakan Observatory holds first place world-wide in the number of new flaring stars discovered. The role of flaring stars has been shown to be one of the early stages in the evolution of most stars. The question of the dependence of the amplitude-frequency characteristics of flaring stars on other variables and on the age of the system in which they reside has been formulated and partially resolved.

We know that prior to the middle 1960s, the possibilities of extragalactic research in our country were limited due to the lack of powerful telescopes. With the introduction of wide-angle telescopes of the Schmitt system with their gigantic prisms at Byurakan, the situation has changed abruptly. In the past 10 years, the Byurakan Observatory has "monopolized" world research with the discovery of galaxies having excess UV radiation in their spectrum: in the literature this has become known as Markaryan galaxies. Out of 1200 galaxies of this type which are of enormous scientific interest, over 90 percent were discovered at Byurakan. Due to the work of this observatory, we now know of about 10 times more Seifert galaxies with particularly active nuclei; this permitted us to study the nature of these objects and establish their genesis from quasars. New types of galactic systems have been discovered; only one of them, Shakhbazyan-1, has an entire series of studies devoted to it in the world literature. A new, large telescope with a mirror diameter of 2.6 meters recently entered the structure of Byurakan (in the USSR its dimensions are only inferior to the 6-meter telescope at Zelenchuk). The use of this telescope has already led to new, interesting discoveries in the field of galactic nebulas. With the aid of the telescope situated on the Soyuz-13 satellite, coworkers at Byurakan have obtained UV spectra of very weak stars (of the 13th magnitude): this significantly surpasses the results obtained in observations made from other satellites.

The Institute of Radiophysics and Electronics, ArmSSR Academy of Sciences, achieved great success in developing highly-sensitive radiometric equipment: a parametric amplifier for the 4 millimeter range and others was developed. Methods for using polarized effects in precision SHF-phasometry have been proposed, developed and implemented. Another important research trend at this institute is the development of small high-sensitivity photoelectric converters of angular motion. The results of the institute's work have been very valuable in space and natural resource research.

In addition to the Institute of Radiophysics and Electronics, physics work is done in Armenia at three large scientific centers: Yerevan Physics Institute, Yerevan University, and the ArmSSR Academy of Sciences Institue of Physical Research. One of the most significant successes of our physicists, the speaker noted, was the development of a theory of transient emission with whose aid were studied radiation processes. Monophoton nonlinear phenomena in gases were first studied at the Institute of Physical Research.

New crystals for laser electronics have been grown and studied at the institute; a two-frequency ruby laser was created for the first time and a single-crystal emerald was used in laser amplifiers of the millimeter range.

Armenia is a republic with a developed chemical industry; therefore chemical scientists have always been valued in the academy. At the Institue of Chemical Physics, much emphasis is placed on research into the mechanics of chemical reactions. A kinetic method for the accretion of radicals via freezing was developed there, which permits the study of their behavior in concentrations. This made it possible to study the mechanics of several oxidation and decomposition reactions. A new effect of heterogeneous-catalytic decomposition of peroxides into radicals, with partial transition of the radical into the gaseous phase, was discovered. At the institute a new method was proposed for producing esp^cially pure heat-proof compounds: carbides, borides, silicides, and nitrides. This is only part of the work on self-propagating high-temperature synthesis. In collaboration with the USSR Academy of Sciences Institute of Chemical Physics, technology was developed to produce molybdenum disilicide that has been incorporated at the Kirovakan Plant of High-Temperature Heaters. Several other studies are carried out by the institute at plants of the republic's chemical industry.

At the Institute of Fine and Organic Chemistry, more than one thousand new substances are synthesized every two years to demonstrate the connection between their chemical structure and their effect on the organism. A basic practical goal is the search for new drugs to treat cardiovascular, nervous, and mental diseases and against malignant neoplasms.

Based on the development of chemistry of non-limiting and heterocyclic compounds, and the research and development of medicinal plants of local flora, nine highly effective medicinal compounds have been introduced into medical practice.

Successful work has been done at the Institute of Biochemistry, which specializes in neurochemistry. Fundamental research into physiologically highly-active neurohormones of the central nervous system has been done here: biologically active peptides, metal-containing proteins, and proteolipids. The discovery and isolation of some new polypeptide hormones associated with the hypothalamus should be noted, as well as the isolation of a copper-containing protein called neurocuprein from the gray and white cerebral matter. The institute has many qualified personnel and has been able to establish broad international relations.

The Institute of Microbiology has created a large collection of microbial cultures, among which some toxins are represented by the richest collection of strains in the country.

The Institute of Agrochemical Problems and Hydroponics, one of the pioneers of hydroponics in the Soviet Union, achieved significant results in industrial hydroponic cultivation of aromatic geranium, medicinal plants, and nursery-grown grapes.

Important research is being done at the Institute of Botany and Botanical Gardens on flora of Armenia: seven volumes of the 10-volume edition entitled "Flora of Armenia" have already been published; an original theory of aging of higher plants has been developed. Sevan Hydrobiological Station has done great work in studying the biological cycle and productivity of water ecosystems of Lake Sevan.

As a mountainous country, the work of geologists is of major value for Armenia. In particular, the basic patterns of arrangement of major minerals have been shown and theoretical foundations have been elaborated for their search.

Production of copper has existed for 100 years in Armenia. Due to the discovery of copper and molybdenum deposits in the Soviet period, the production of copper has not only expanded but the great production of molybdenum concentrates has been organized as well. At the Institute of Geological Sciences research is being conducted on a high level into the metallogeny of Armenia; more detailed metallogenic maps have been drawn up.

At the Institute of Geophysics and Engineering Seismology, a chronological catalogue of earthquake foci and a cumulative catalogue of intense earthquake foci in Armenia has been drawn up methods have been proposed and approved for comprehensive geological and geophysical, seismological and engineering-seismological research to determine the seismic hazard of the construction sites of nuclear electric power plants. But despite several interesting studies on engineering seismology, the republic has still not highly developed seismologic science capable of predicting earthquakes. Its development is planned: ArmSSR Academy of Sciences needs help from USSR Academy of Sciences.

The activity of ArmSSR Academy of Sciences in the social sciences is extremely diverse. A large number of monographs on history, language, and art of Armenia has been published. The Institute of History created a fundamental eight-volume work "History of the Armenian People". In 1978 occurred the sesquicentennial of East Armenia's federation with Russia, when the Armenian people were saved from destruction. Works have been published on the evaluation of historical meaning of the transition to a new stage in the history of the Armenian people, characterized by the gorwing collaboration with the brotherly Russian people and other peoples forming the USSR. It is gratifying to note that the most important place in historical research is occupied by works on the Soviet period of Armenian history—a period of the ultimate blossoming of all forms of its political, economic, and cultural life.

An important, complex task is the scientific study of the future development of the republic's national economy. Both industry and agriculture of Armenia are multi-sectorial; thus the composition of economic predictions is not an easy task. The first great step in this direction was taken in 1977 with the publication of the Institute of Economics' work "On Major Trends in Socioeconomic Development of the Republic Before 1990". This work has been presented to the State Planning Committee and the leading organs of the republic.

The Institute of Philosophy and Law, in addition to problems of history of Armenian philosophy and other issues, is working intensively on a comprehensive study of the socio-philosophical aspects of functioning and development of science in the period of scientific and technical revolution. Over 40 monographs and collections have been published on the subject.

The Institute of Archeology and Ethnography has conducted important work in archeology, especially the excavation of such valuable historical treasures as the Karmir-Blur, Erebuni, Artashat, Garni, and so forth.

The Institute of Literature imeni M. Abegyan created a five-volume "History of Soviet Armenian Literature". Among the achievements of the Institute of Language imeni R. Acharyan is the creation of a three-volume scientific grammar of the Armenian language the completion of work on the four-volume "Explanatory Dictionary of Modern Armenian".

The speaker drew attention to the fact that the activity of the ArmSSR Academy of Sciences does not strive to develop all disciplines, but selects those directions in which it can focus all efforts to achieve valuable results. Related to such trends are, in mathematics, the theory of functions, integral geometry; in astrophysics, non-stationary effects in outer space; in radiophysics and radio engineering, the use of effects in the SHF range to solve concrete technical problems; in chemistry, the study of mechanics of chemical reactions, synthesis of new compounds; in biochemistry, neurochemistry.

Wherever this principle is not followed, indicated the speaker, in the scientific activity of the institutes of the academy there are shortcomings, especially in multiple themes which leads to the scattering of scientific efforts. Patent licensing work is not being done actively enough. The productivity and quality of scientific research work must be raised: it is to a great extent defined by the qualification of scientific personnel. In this regard, Armenia has propitious horizons, since one-third of the scientific and scientific and technical workers of the academy are under 30 years of age.

V. A. Ambartsumyan noted the acute problem of providing institutes with scientific equipment, especially imported hardware. In resolving this problem, great help could be rendered by the USSR Academy of Sciences. The limit of subscriptions to foreign scientific journals must also be increased.

The current computer pool of the ArmSSR Academy of Sciences Computer Center does not meet modern requirements and does not permit the study of systems programming nor the establishment of computer time-sharing for the scientific institutions of the republic. The arrangement of test production is not going well.

In conclusion, the speaker stressed that the activity of the institutes of the ArmSSR Academy of Sciences, to a great degree, depends on interaction with the corresponding institutions of the USSR Academy of Sciences, and also with academies of sciences of brother republics. In particular, scientific ties were recently intensified with the academies of sciences of Georgia and Azerbaydzhan.

V. A. Ambartsumyan expressed gratitude to the USSR Academy of Sciences Commission which became deeply familiarized with the activity of the ArmSSR Academy of Sciences' activities and noted that advice and recommendations made by the commission have already made significant contributions to the scientific institutions of the ArmSSR Academy of Sciences.

A joint report was delivered by B. S. Sokolov, chairman of the commission of the Presidium of the USSR Academy of Sciences familiar with activity of the ArmSSR Academy of Sciences.

B. S. Sokolov emphasized that since its inception, the ArmSSR Academy of Sciences chose the completely proper path: it does not copy the activity of USSR Academy of Sciences and other academies, but develops its own powerful aspects. The ArmSSR Academy of Sciences, therefore, now represents an original scientific organization with great achievements.

A scientific center of world renown, the Byurakan Observatory, conducts unique astrophysical research. Armenia has had its own, long known mathematical school. Research of Armenian scholars in the field of radiophysics of superhigh frequencies occupies a firm place in modern science. Research in physical chemistry offers exceeding interest.

Great deposits of minerals exist in Armenia; a detailed plan of assimilation ofnatural resources has been drawn up. Work is now being intensively done in engineering seismology.

Research done by Armenian scientists in neurophysiology and neurochemistry is at the forefront in our country.

Very valuable experience has been gained through research of biocenoses and adjustment of the ecosystems of Lake Sevan because of steps taken there to develop the republic's energy. A unique biological and geographical object like Sevan is becoming a natural model for important research by the State: the results should be considered when similar steps are organized for Baykal and other regions.

In many scientific trends, Armenian scientists have achieved great successes and practical works which have been incorporated into production.

However, noted B. S. Sokolov, at some institutes of the republic's Academy of Sciences efforts are inadequately concentrated on the main trends of research, small topics are retained, and qualified personnel are hard to get. The computer pool of the Computer Center needs renewal. Some institutes do not have enough modern equipment. Arrangement of the Library of the ArmSSR Academy of Sciences for the Geological Museum with its unique collection is not proceeding satisfactorily. Serious attention must be paid to the construction of new sites for the institutes.

In conclusion, B. S. Sokolov noted that party and council leadership of the republic is attentively relating to the needs of the Academy of Sciences and is promoting the development of science in Armenia.

Discussion of Report

Academician A. A. Bayev gave high evaluation to the achievements of Armenian scientists in the major branches of biology. In particular, he noted the Institute of Biochemistry where a very important direction is being taken in the study of chemical processes of the cerebrum.

The situation at the Institute of Experimental Biology, created to develop research in molecular biology but not yet justifying its purpose is not completely favorable. Some improvement in the Institute's work occurred recently, but there are still multiple themes, incompatible directions of research and other organizational shortcomings.

A. A. Bayev called attention of the leadership of the ArmSSR Academy of Sciences to take organizational steps in this institution aimed at fulfilling the resolution of the CPSU Central Committee and USSR Council of Ministers entitled "On Measures to Accelerate Development of Molecular Biology and Molecular Genetics and Use of These Achievements in the National Economy." In conclusion, A. A. Bayev emphasized the proposal to publish a new journal NEUROCHEMISTRY at the ArmSSR Academy of Sciences, to become a journal of world-wide standing.

E. R. Mustel', Corresponding Member of USSR Academy of Sciences, expressed the desire that the Byurakan Observatory more actively coordinate leading extragalactic research in the USSR.

Academician I. V. Tananayev suggested improvement in the activity of the Institute of General and Inorganic Chemistry of the ArmSSR Academy of Sciences.

Academician P. N. Fedoseyev, Vice President of USSR Academy of Sciences noted the active work of the Institute of Economics of ArmSSR Academy of Sciences. At the same time there is a state of comminution of economics institutions of the republic which must be overcome. Speaking of the development of historical science in Armenia, P. N. Fedoseyev called attention to the great meaning of activity of Armenian historians and archeologists, but also expressed the wish that historians would more attentively coordinate the study of complex historical issues with research being done at institutes of the Department of History of USSR Academy of Sciences especially the Institute of USSR History.

Academician N. G. Basov stressed the importance of research being conducted at the Institute of Radio Engineering and Electronics, the Institute of Physical Research of ArmSSR Academy of Sciences, at Yerevan University. He noted the important role played in the development of laser radiophysics in the Soviet Union by achievements of the ArmSSR Academy of Sciences and industry of Armenia. In particular, a high-quality ruby was first produced in Armenia and this made it possible to solve several important national economic problems. N. G. Basov noted the need for a study of the problems of optical computer technology in ArmSSR Academy of Sciences.

G. K. Skryabin, Corresponding Member USSR Academy of Sciences noted the great work done by the ArmSSR Academy of Sciences Institute of Microbiology which, in several trends, holds the leading position in the Soviet Union. He called attention of the Presidium of USSR Academy of Sciences to the problems with scientific equipment at institutions of ArmSSR Academy of Sciences and opined the need to aid his Armenian colleagues in this direction.

The discussion was summed up by Academician V. A. Kotel'nikov, Vice-President USSR Academy of Sciences who emphasized that ArmSSR Academy of Sciences has great achievements and is one of the leading republican academies. V. A. Kotel'nikov expressed his confidence that ArmSSR Academy of Sciences and its Presidium will consider the critical remarks made to it and will achieve even higher results.

Resolution

The USSR Academy of Sciences Presidium approved the scientific and scientific-organizational activity of ArmSSR Academy of Sciences. Basic directions of scientific research at institutions of ArmSSR Academy of Sciences were confirmed.

It was recommended to ArmSSR Academy of Sciences that it consider the comments and suggestions of the commission of scientists of USSR Academy of Sciences in its work; that is concentrate efforts and means to perform research along the main lines with guidance from resolutions of the 25th CPSU Congress on the development of science and the national economy of the republic. Measures should be taken to develop new scientific directions at the academy:

at the Institute of Mathematics: geometric theory of probabilities; at the Computer Center: computer mathematics, numerical methods of mathematical physics, systems programming;
at the Institute of Inorganic Chemistry: research of inorganic polymers, ion exchange in inorganic systems, and study of theoretically new methods of complex reprocessing of raw material containing light elements.

It was proposed to intensify cooperation and creative ties of academical institutes with scientific institutions and vuzes of the republic.

A decision was adopted to reexamine the structure of the Computer Center, Institute of Mechanics, Institute of Physical Research, Institute of Experimental Biology, Institute of Zoology, Institute of Arts, bearing in mind the recommendations made by the USSR Academy of Sciences commission of scientists.

It was felt advisable to organize an interinstitute methods center of biological and chemical orientation to more efficiently utilize modern equipment.

The USSR Academy of Sciences Computer Center has been directed to study a program of development for a tri-level computer time-sharing system for institutions of ArmSSR Academy of Sciences.

The USSR Academy of Sciences Division of Biochemistry, Biophysics, and Chemistry of Physiologically Active Compounds and USSR Academy of Sciences Division of Physiology have been directed to consider coordinating on-going research in the USSR in the field of neurochemistry.

The USSR Academy of Sciences editorial and publishing council jointly with the Presidium of ArmSSR Academy of Sciences have been instructed to prepare a proposal on the creation of an All-Union journal NEUROCHEMISTRY.

The Presidium of USSR Academy of Sciences also resolved to ask the ArmSSR Council of Ministers to cooperate with ArmSSR Academy of Sciences in solving questions associated with expansion of industrial areas, development of the material and technical base of scientific institutions, and transmission to industry of some of the work program of test productions of ArmSSR Academy of Sciences.



8617
CSO: 1870

SCIENTISTS AND SCIENTIFIC ORGANIZATIONS

## ON THE ACTIVITY OF THE DIVISION OF OCEANOLOGY, ATMOSPHERIC PHYSICS AND GEOGRAPHY

Moscow VESTNIK AN SSSR in Russian No 2, 1979 pp 11-18

[Report by L. M. Brekhovskikh, Academician-Secretary, Division of Oceanology, Atmospheric Physics, and Geography, USSR Academy of Sciences]

[Text] The USSR Academy of Sciences Division of Oceanology, Atmospheric Physics and Geography was formed in 1968. The division consists of the Institute of Oceanology imeni P. P. Shirshov, the Institute of Atmospheric Physics, the Institute of Geography, the Institute of Water Problems, and the Institute of Limnology. The division effects scientific and methods leadership along with the institutes of the Siberian Division, Far Eastern Science Center and branches of USSR Academy of Sciences, participates in the scientific and methods leadership of the Acoustics Institute and institutions (according to the division profile) of academies of sciences of Union republics, and also cooperates in the development of research and its coordination in the field of oceanology, atmospheric physics, geography, geocryology, water problems and limnology in many institutions of other agencies.

The Scientific Council on Earth Cryology and the Geomorphologic Commission work in the division; the journals Izvestiya AN SSSR, Seriya Geograficheskaya; Izvestiya AN SSSR, Seriya Fizika Atmosfery i Okeana; Okeanologiya; Geomorfologiya; and Vodnyye Resursy are published there.

Activity of the Division of Oceanology, Atmospheric Physics, and Geography was discussed at a meeting of the USSR Academy of Sciences Presidium. Academician L. M. Brekhovskikh, academician-secretary of the division, presented a report.

A series of studies on ocean acoustics has been completed. The monograph "Ocean Acoustics" which was devised on the basis of these studies won the USSR State Prize in 1976.

A large series of studies on the propagation of laser emission in the atmosphere has been completed. Data were obtained on the major optical characteristics of air-borne particles and statistical patterns of variation were revealed.

A study of twilight effects and observation data from spacecraft were used to develop methods of optical sensing of the high layers of the atmosphere. Based on measurements of reflected and inherent emission of the Earth's surface and atmosphere in the visible and IR ranges from Earth satellites Kosmos-149, -243, -320 and -384, methods of remote analysis were designed for some geographical parameters of the atmosphere. Data obtained with these methods have been used to study Earth's natural resources using aerospace techniques.

A spectroscopic devices was designed and expeditionary measurements of small impurities throughout the atmosphere were analyzed.

The study of natural resources and the environment were recently expanded significantly. Publication is completed of 14 monographs in the series "Natural Conditions and Resources of the USSR"; the monograph "Resources of the Biosphere in the Territory of the USSR: Scientific Bases of Rational Use and Conservation" was published.

A plan was developed to form a Baykal Nature Conservation Zone; tentative prognosis of a change in the environment of the Aral Sea has been made; a system has been proposed for measures to transform and utilize the swamps of Western Siberia.

Using modern geophysical methods, a comprehensive study is being made of the natural ecosystems and anthropogenic transformation, including a comprehensive program of CMEA and the Interkosmos Program.

The modern dynamics of glaciers has been studied; a prognosis of evolution of pulsating glaciers was developed for the Caucasus, Tyan'-Shan', and Pamir; work has been done to compose a catalog of USSR glaciers.

Cooperation with geographers of different countries is being developed. In collaboration with Cuban scientists, a National Atlas of Cuba was put together (this work won the USSR State Prize). In collaboration with Indian geographers, papers were published on the economic-geographic regionalization of India. Soviet-French studies have been done on the "Alps-Caucasus." Cooperative studies have been done on physical and economic geography with scientists of Poland, Czechoslovakia, Bulgaria, East Germany, and other countries.

The Division of Oceanology, Atmospheric Physics, and Geography concentrates its work on the solution of fundamental scientific problems, giving particular meaning to problems which are important to the economic development of our country.

One of the chief achievements in oceanology was the discovery in the ocean by the Polygon-70 expedition from the Institute of Oceanology of meso-scale eddies (on the order of hundreds of kilometers in size) in which the primary energy of oceanic flows is concentrated. This discovery, confirmed by the data of other experiments, radically altered the then current notion about flows in the ocean.

With the aid of hydrophysical probes of increased resolution designed at the Institute of Oceanology, an evolved, delicate vertical structure of the ocean was detected and its universal prevalence was established.

A global numerical model of ocean and atmosphere interaction was elaborated it theoretically possible to simulate the climate. The Tropeks-72 (Tropical Experiment) and ATEP-74 (Atlantic Tropical Experiment) were carried out with wide and comprehensive studies of atmospheric and oceanic interaction.

A specially designed device was used to study petroleum contamination of the world's oceans. Dispersants have been developed to remove the petroleum film. Natural tests of three sorbents were successful. These agents were highly effective in cleaning the port landing area of petroleum, mazut, and diesel fuel films.

Numerous data on the geology of oceans were first reflected on maps of bed sediments of the world's oceans, mineralogical charts, geochemical, sediment physical property and other charts.

A large cycle of research work on iron-manganese concretions at the ocean bottom and of fields of propagation of metal-bearing sediments is completed.

An important theoretical assumption was advanced on the optimum zones of petroleum and gas formation in landing areas as the largest foci of natural generation of different phased systems of hydrocarbons under the specific circumstances of an ocean-type sedimentary layer. New shelf and sea areas have shown promise of petroleum and gas content. Data have been obtained on the relief of the crystalline foundation and structure of the sedimentary cover beneath the landing area of the Middle Caspian; these data permitted recommendations to be made for petroleum and gas prospecting work.

Much attention was given to studying of distributive features of biological zones in the ocean. Mathematical models of the function of biological communities of the pelagic zone were constructed. A structural-functional analysis of biological communities was done of the most powerful bioproductive systems of the world ocean; the production of biological communities, their individual trophic levels and groups was evaluated.

A geomorphologic commission coordinated research on vital scientific problems "Surfaces of Planation and Weathering Crust of the USSR" and "Modern Tectonic Movements."

A great deal of attention has been given to studying the productive forces of Siberia, questions of efficient utilization, conservation, and reproduction of natural resources, geographic rationale for future development of regions on the BAM route. Patterns of formation of the population have been revealed in regions of new assimilation in Siberia. A prognosis was developed for population dynamics in this region.

Using materials from the Far East, methods of geographic prognosis have been developed for environmental change due to the paleoclimate on the global scale. Patterns of transformation have been established for technogenic matter due to the complex of mining enterprises in the humid climate of the Seacoast. Detailed economic regionalization of the eastern portion of the BAM zone has been implemented.

Ecosystems in the Zeya Basin have been studied. As as result of these studies a prognosis was made for change in ecosystems affected by the Zeya reservoir.

Scientific foundations have been developed for controlling water resources of the country. Research has been done on processes of global and regional moisture exchange. Methods have been designed to determine the water content in the atmosphere, snow, and soils; methods were proposed for evaluating the amount of precipitation based on satellite data.

A map of the underground runoff of our country has been drawn up and was evaluated in the world water balance. Methods of regional evaluation of resources of subterranean water were designed for problems of the General Plan of Comprehensive Utilization and Conservation of Water Resources of the USSR. Work is complete on the quantitative evaluation of subterranean runoff into the world ocean under diverse natural conditions.

Foundations of a theory of control of river runoff and fluctuation in the level of closed basins have been elaborated; a mathematical model of the complex water management system has been designed; the possibility of maintaining favorable conditions of the Caspian Sea level with significant economy of water fed from other basins has been substantiated.

A prediction of possible changes until 1990 in water quality of the Ivan'ko Reservoir--a primary source of water supply of Moscow--has been drawn up. A prediction of change in the biological and chemical conditions of lakes in the Northwest European territory of the Soviet Union and the Karelian Peninsula was written in connection with transfer of some of the runoff to the south. Research has been done on predicting water quality and overgrowth of reservoirs in various regions of the country (including the BAM region).

The hydrometerologic conditions, water and thermal balance of the Baykal, Bratsk reservoir, hydrochemistry of Baykal and its tributaries, biological productivity of Baykal and the effect on it of agricultural activity have been studied. Deep water dives in a bathysphere made in Baykal permitted direct observation of the nature of deposition of sedimentary layers in the Baykal depression.

Water resources of the Karelian Peninsula have been evaluated; natural features of Karelian basins were studied; the effect of industrial and domestic discharge on water quality, water fauna and flora were determined. Research on the effect of the forestation of catchment areas on the formation of surface water resources of the Komi ASSR have been completed.

A large amount of work has been done in the field of geocryology. Monographic descriptions have been written of geocryologic conditions of mountain regions of Siberia and Yakutiya. The maximum thickness of rock cooled below 0 degrees Celsius on the Earth has been established. A considerable discontinuity of frozen layers was found in the mountainous part of our country's northeast. In conjunction with USSR State Committee for Construction, a geocryologic map of the Soviet Union was drawn up. Geocryologic conditions of the territory of Mongolia were investigated and a geocryologic map was composed. A map was drawn of the cryogeomorphologic regionalization of Siberia and the Far East.

In collaboration with sector organizations, engineering and biologic natural conservation recommendations have been made for the region of construction and exploitation of structures, extraction and transportation of gas in northern Siberia. Method were designed for hydrothermal land reclamation of soils in the zone of propagation of perennially frozen soils and recommendations were made for liman irrigation of Central Yakutiya. In collaboration with the Institute of Hydrotechnics, theoretical foundations and engineering methods were developed for predicting degradation of permafrost with the construction of reservoirs.

In concluding the speaker touched upon the scientific and organizational activity of the Division of Oceanology, Atmospheric Physics, and Geography. A general meeting of the division regularly hears reports on major scientific achievements, institute reports on their scientific activity, reports on vital problems of modern science.

A considerable place in the work of the division is occupied by the organization of scientific sessions. Sessions run by the division were devoted to global research of the atmosphere and weather prediction; prediction of the consequences of human actions on the environment; the study of natural resources of the Komi ASSR; acoustics of the ocean and hydrophysics; new methods of studying ocean waters, atmospheric processes, relief of the dry land, natural water and glaciers, problems of the country's water balance; remote sensing of the environment from space; problems of solar-ground links, etc. The session devoted to climatic problems is worthy of special note. It was called by the division in 1977 in conjunction with the USSR State Committee on Hydrometeorlogy and Environmental Control, USSR Academy of Sciences Scientific Committee on the Problem "Weather Prediction", and the USSR Academy of Sciences Scientific Council on Problems of the Biosphere. At the session summaries of research into the genesis and prognosis of the climate were given and recommendations were made for further development of this research.

The division took an active part in elaborating the Comprehensive Program of Scientific and Technical Progress and its socioeconomic consequences for 1976-1990, and scientific and technical prognosis of efficient utilization and conservation of water resources until 2000.

Especially important scientific and technical issues were covered by special meetings of the division bureau. The bureau also discussed questions of development of creative collaboration of scientific institutions of the division with production and acceleration of incorporation of results of scientific developments; it discussed steps toward further improvement of higher education in its profile, means of expanding ties with scientific institutions of the USSR Ministry of Education, compulsory and extracurricular institutions. Questions of training scientific personnel are regularly examined at bureau meetings.

The division devotes much attention to multilateral cooperation with academies of sciences of the socialist countries on the comprehensive program "Planetary Geophysical Research," the state of work on the PIGAP program (program of study of global atmospheric processes), activity of the Coordination Center of the Institute of Oceanology on the problem of member countries of CMEA "Study of Chemical, Physical, Biological, and Other Process of Major regions of the World Ocean and Development of Modern Technical Means for Efficient Study and Mastery of Its Resources."

Stressing the successful development of scientific disciplines related to the division's competency, the speaker noted problems which division institutions have encountered due to the lack of necessary equipment, modern technical means for expeditionary research, work sites, and scientific personnel, especially in several new specializations.

Discussion of the Report

Academician V. V. Shuleykin touched on the problem of long-term weather predictions which, he feels, does not receive due attention from the Academy of Sciences. In studying this problem, he said, scientific policies must be completely altered. No matter how perfect the differential equations written by the experts are, they are not effective if they are integrated without considering boundary conditions. Boundary conditions, however, can not be considered since we do not know them: we have no continuous data about what goes on on the surface of the world ocean. Furthermore, to solve this problem, research of the ocean's waters must be carried out in continuous association with research of atmospheric physics.

K. Ya. Kondrct'yev, Corresponding Member of USSR Academy of Sciences, noted that the formation of the Division of Oceanology, Atmospheric Physics, and Geography in the Academy of Sciences promoted the more effective development of these major sections of Earth science. In the 10 years since the organization of the division, however, scientific problems have arisen, especially in the study of the environment and natural resources. These new problems are difficult to solve using the same efforts which the division now has available. For example, this is the problem with the climate which has long since been the subject not only of physics and chemistry, but of biogeophysics as well. It is quite clear that without a study of various interacting processes occurring in organic and inorganic nature, there is no chance of answering the question of why and how the climate changes. K. Ya. Kondrat'yev agreed with V. V. Shuleykin on the importance of considering boundary conditions in long-term weather forecasts. In fact, he said, it is not enough to use initial data alone for a forecast.

It is now impossible to tell with certainty what is happening with the climate, mainly because there is not enough factual data for the entire globe. This data should mainly be obtained by satellites. Thus satellite climatology becomes extremely important. Research of the weather and climate on other planets is extremely important to understand the patterns of the Earth's climate: close contacts must be maintained with astrophysicists for this reason.

The make-up of the division should more fully correspond with the new problems. More efficient mechanisms and forms of scientific cooperation are needed. In particular, an interdisciplinary program on the climate is needed which could unite members of various scientific trends and form a united front of research, which does not yet exist. Furthermore, and this concerns not only the problem of the climate, the division should more broadly coordinate research in its profile throughout the entire country.

Yu. A. Izrael', Corresponding Member of USSR Academy of Sciences, characterized the problems which face scientists in solving problems of long-term weather forecasting and climatic change, as well as the study of the geophysical aspects of ecology.

In research on hydrometeorology associated with solving the problem of long-term weather forecasting, he said, Soviet experts are actively collaborating with scientists of all countries. The PIGAP program is an example of this collaboration. Work in this program should give valuable data for improving methods of long-term weather forecasts.

A program associated with long-term weather forecasts continues to be formed. This problem requires special attention. Soviet scientists are doing a lot of work in weather forecasting. The ideas of Academician G. I. Marchuk on long-term prediction are very interesting. But in addition to these ideas and plans, a good system of observations is necessary, a system of data production which could be used to implement these ideas and plans. Therefore, another important problem is the creation of a continuous system of global meteorological surveying in which a great role should be given to aerospace observation systems. Consequently, a more rapid creation of a geostationary meteorologic satellite is becoming more and more important.

Closely allied with work on long-term weather prediction is work on climate study. It is still impossible to accurately describe the climate even for the near future, and our future depends heavily on this. On the suggestion of scientists of USSR Academy of Sciences and the USSR State Committee on Hydrometeorology and Environmental Control, it was decided to create a national Soviet program on climate studies. This program will unite various forms of research into a unified front.

As concerns the contribution of the Division of Oceanology, Atmospheric Physics, and Geography to the problem of environmental protection, it is mainly linked with solving a series of ecological questions. Cooperation has been arranged between institutions of USSR Academy of Sciences and the USSR State Committee on Hydrometeorology and Environmental Control. Hopefully it could be even closer.

Academician A. M. Obukhov emphasized that the Division of Oceanology, Atmospheric Physics, and Geography had significantly promoted a rise in the overall level of scientific research in its pertinent fields. Division sessions generally are creative and stimulate the use of new atmospheric and oceanographic research methods. The use of fine methods of spectroscopy to indicate atmospheric impurities, the use of natural thermal emission in the SHF range in problems of "aerospace geography" and oceanology could be given as examples. Furthermore, the division could play a greater role in drawing the attention of scientists working on fundamental problems to the practical needs of various agencies. This is especially germane for atmospheric physics.

Academician A. V. Sidorenko stated that when the Division of Oceanology, Atmospheric Physics, and Geography had just been formed there was insufficient attention given to its strengthening. The resources of some institutions in the division did not correspond to new problems. This is still the situation with the Institute of Geography, Institute of Limnology. The Institute of Water Problems also was in a complex situation for a long time: it had basically been formed only on paper. Thus now primary attention must be given to reinforcing the material and technical base of the institutes.

It is very important to intensify the role of the division both in the coordination of research being conducted by institutions of the USSR Academy of Sciences and republic academies as well as in coordinating interdisciplinary and interagency research. This will aid in more clearly defining the general line of division activities.

Academician I. P. Gerasimov spoke of the need to strengthen the material and technical base of institutes, especially the Institute of Geography, whose resources do not correspond to problems which it has to solve at today's level of geographic science. He also touched on the question of drawing up a program of fundamental research. In our division, he stated, we should develop or modernize programs to study the world oceans, climate, and the environment. An environmental program should be comprehensive and include biological, geographic, economic,and sociological research.

A. F. Treshnikov, Corresponding Member USSR Academy of Sciences, noted that the Arctic and Antarctic play a deciding role in shaping weather, and the study of these regions of the globe is very important in making forecasts. The USSR Academy of Sciences has an Interagency Commission on the Study of the Antarctic. There is no coordinating unit for arctic research, but one is needed. Various agencies of our country are now working in the polar region, including the Arctic Ocean. But this work is not coordinated, there is no general line, no strictly scientific basis. Perhaps it is not only a coordinating unit which is necessary, but a scientific research organization on questions of the Arctic.

Academician A. P. Aleksandrov, president of the USSR Academy of Sciences noted the need for creating climate programs which would include research connected with the design of means of climate control, as well as work on the paleoclimate.

Resolution

The Presidium of the USSR Academy of Sciences approved the activities of the Division of Oceanology, Atmospheric Physics, and Geography of the USSR Academy of Sciences.

The chief task of scientific institutions of the division is the conduct of research on natural processes in the water and air envelopes and on the dry land of Earth using the latest methods and means with the goal of effective use and protection of resources and forecasting their evolution.

In the future the scientific and research work of the institutes of the division will be concentrated in the following areas:

the study of physical, chemical, biological, and geological processes in the world ocean and its seas; the study of the interaction of ocean, dry land and atmosphere to find means of efficient utilization of resources and to ensure long-term weather forecasts; development of scientific means of prevention of pollution of the ocean; creation of new ways and means to study the world's oceans and, above all, multispectral space photographs and remote sensing;

improvement of methods of long-term weather forecasting on the basis of the study of physical, chemical and other processes in the Earth's atmosphere and on other planets; fuller consideration of the interaction of atmosphere, continents, and oceans; study of climates of the past, development of a theory of climate and design of methods of prediction of natural and man-made changes; a search for principles of artificial impact on the weather and climate; and development of new methods of atmospheric research;

the search for more efficient means of utilization, protection, and transformation of the natural environment; elaboration of prognoses of its change due to increasing rates of technical advancement; establishment of scientific bases of geoecological monitoring of the state of the environment; and ways and means of purposeful control of natural and natural-technical systems;

development of scientific bases of control of conditions, resources, and quality of dry land waters for their optimum utilization and protection based on studies of water and moisture exchange in the atmosphere dry land-ocean system;

a study of patterns of formaton of cryolithozones; creation of scientific foundations and methods of control of cryogenic processes for national economic assimilation of the region of seasonal and perenial frozen rock and the search for methods of recultivation of disturbed natural landscapes.

The Presidium called attention of the division to the need to intensify and expand the coordination of research both with institutions of the ministries and agencies, and with institutions of academies of sciences of Union republics; and with institutes of other divisions of USSR Academy of Sciences as well (primarily the Division of General Physics and Astronomy, Division of Mechanics and Control Processes, Division of General Biology, division of Physical Chemistry and Technology of Inorganic Materials); to more widely utilize the resources of interdisciplinary cooperation (by using optimum forms of organizational communication with other institutions).

A resolution was taken on the need of substantial improvement of the material, technical, and equipment provision of the institutes, and also on the future development of experimental foundations, especially for the development of modern methods of study of the environment using aerospace means, remote sensing, modern computer technique, and so forth.



8617
CSO:1870

PUBLICATIONS

UDC 621.396.61:621.385.6

ACCELERATED ELECTRON BEAM TRANSMITTER

Moscow ELEMENTY PEREDATCHIKOV S USKORENNYMI ELEKTRONNYMI PUCHKAMI [Elements of Transmitters with Accelerated Electron Beams] in Russian 1978 signed to press 10 February 1978 pp 2-4, 126,127

[Annotation, foreword, and table of contents of a book by Boris Aleksandrovich Snedkov, Izd-vo "Svyaz'", 1,300 copies, 128 pages, with illustrations]

[Text] Possibilities for using resonantly accelerated electron beams in transmitter elements are described. The book provides calculations of current pulses in bunchers and methods of electron resonant acceleration. Basic attention is placed on examination of transmitter element operating principles and their designed features are also examined.

The book is intended for engineering and technical workers who do the project planning of transmitters.

Foreword

Type "O" and "M" electrovacuum instruments are being used in high-power microwave transmitters: LBV [travelling wave tube], klystrons, and magnetrons. At the present time specific rules for the construction of transmitter circuits as well as rules for the elaboration of electronic instruments which have now become classic have been laid down. The capabilities of the classic circuits do not always satisfy the growing requirements of modern communications equipment. Therefore, the author has for several years directed his efforts at creation of the theory of new transmitter hybrid circuits using the elements of tuned amplifiers and the elements of floating-tube klystrons. The hybrid devices possess special energy characteristics and their analysis is undoubtedly of interest to readers.

Examined in Chapter 1 are possibilities for using resonantly accelerated electron beams in transmitter elements. A theoretically new approach is being used--a generator with an external excitation is looked upon as a stage to which, along with a dc source, is fed an auxiliary HF feed source, which materially increases the kinetic energy of the electron beam. Practice has shown that the electron beams must possess a relatively homogeneous energy in order to obtain highly effective hybrid devices.

Chapter 2 sets down a method of calculating current pulses in bunchers, which makes it easy to find the energy and time characteristics of the electron clusters. Using these characteristics, examined in Chapter 3 are the circuits of the tuned electron amplifiers with monoenergetic beams. Such amplifiers are input as an integral part to the generators with external excitation but, in a number of instances, they can also accomplish independent tasks.

Described in Chapters 4 and 5 are specific devices: electronic antennas, phase inverters, microwave power switches, frequency amplifier and multiplier stages, and circuits of transmitting devices with accumulation of microwave energy in resonant systems. However, the devices examined do not exhaust all the possible advantages of resonant acceleration. Also described in Chapter 4 are several elements of the transmission channel which controls the bunched beams. Here the accent is placed on the capability of transmission of the microwave energy which carries information about the usable signal by an electron beam. Examined in Chapter 5 are the transmitter elements using bunched beams, and attention is also concentrated on the potential capabilities of accumulating the microwave power in the generator's oscillation system and in its electron beam. The design features of the transmitters are discussed in Chapter 6.

The principle of resonant acceleration has been known for a long time and is being widely used in charged particle accelerators. Clear concepts exist on the elaboration and tuning of resonant and waveguide acceleration systems. Particle accelerators are used in high-energy devices, the category to which the output stages of microwave transmitters belong. Nonetheless, resonantly accelerated electron beams are used in transmitter elements only under laboratory conditions now.

The purpose of this book is to familiarize readers with the varied possibilities of using resonantly accelerated beams in transmitted elements using clear examples. Specific calculations of the circuits examined have been reduced, it seems to me, to the most interesting practical point of view.

If readers in their practical activities can use the principles of circuit construction and methods for computing them presented in the book, the author will consider that the job has been accomplished.

The author is obliged to thank his teachers and tutors--Docent G. I. Zhileyko and Professor S. I. Yevtyanov (deceased), who through their advice predetermined the direction the book took.

The author expresses appreciation to readers who participate in discussing the book. Criticism and comments should be sent to Izdatel'stvo "Svyaz'", 101000, Moscow, Chistoprudnyy bul'var 2.

Contents





7869
CSO: 1870

PUBLICATIONS

UDC 621.391 (075.8)

THEORY OF SIGNAL TRANSMISSION IN PROBLEMS

Moscow TEORIYA PEREDACHI SIGNALOV V ZADACHAKH (Theory of Signal Transmission in Problems) in Russian 1978 signed to press 7 Mar 78 pp 2, 351-352

[Annotation and table of contents from a book by Daniel Davydovich Klovskiy and Vladimir Afanas'yevich Shilkin, Izd-vo "Svyaz'", 18,000 copies, 252 pages, with illustrations]

[Text] This is a handbook for rating systems for transmitting information via electrical communication channels. Brief theoretical information in the form of computational procedure is presented prior to formulation of problems in the separate sections which touch upon the comprehensive problems connected with the probability rating for various communication system elements.

The book is intended for students in institutes of communications and similar specialties and can be used by a broad circle of engineering and technical workers who are beginning to assimilate the methods and routines for statistical analysis and synthesis of information transmission systems.

Contents — Page

7869
CSO: 1870

PUBLICATIONS

UDC 621.396.6-762

CAPSULATION OF RADIOELECTRONIC GEAR

Moscow GERMETIZATSIYA RADIOELEKTRONNOY APPARATURY (Capsulation of Radio-electronic Gear) in Russian 1978 signed to press 10 Mar 78 pp 2, 359-360

[Annotation and table of contents from book by Yeva Izrailovna Fridman, Izd-vo "Energiya", 8,000 copies, 360 pages, with illustrations.]

[Text] Examined in the book are questions of capsulation of radio-technical components that are important for REA [radioelectronic gear]. Presented are the most effective methods of protection and modern capsulation materials. The functional dependencies of the basic parameters of polymers on the effect of various climatic factors are shown. Presented are schematics of the capsulation processes and individual examples of the capsulation of several components recommended for use in severe climatic conditions.

The book is intended for engineering and technical and scientific workers in radioelectronics and in similar sectors of industry who are involved in the design and production of components which are protected against climatic effects. The book can be used by students in the corresponding specialties and technical VUZ's.

Contents Page

7869
CSO: 1870

END